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Franklin as a Man of Science and an Inventor.*

[An address delivered by Dr. Edwin J. Houston, Emeritus Professor of Physics, Franklin Institute, on February 21, 1906, on the occasion of the 200th anniversary of the birth of Benjamin Franklin.]

(*Concluded from vol. clxi, p. 316*)

"Fig. 11 is to represent the elevation of a water-spout, wherein, I suppose P P P to be the cone, at first a vacuum, till W W, the rising column of water, has filled so much of it. S S S S, the spiral whirl of air surrounding the vacuum, and continued higher in a close column after the vacuum ends in the point P, till it reaches the cool region of the air. B B, the bush described by Stuart, surrounding the foot of the column of water.

(h) "Now, I suppose this whirl of air will, at first, be as invisible as the air itself, though reaching, in reality, from the water, to the region of cold air, in which our low summer thunder-clouds commonly float; but presently, it will become visible at its extremities. *At its lower end,* by the agitation of the water under the whirling part of the circle, between P and S, forming Stuart's bush, and by the swelling and rising of the water, in the beginning vacu-

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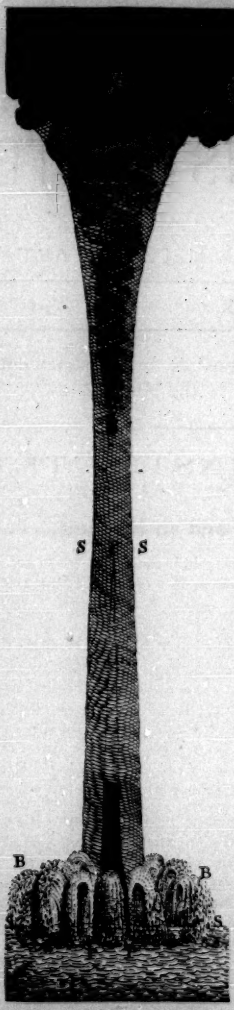


Fig. 11. Elevation of Water Spout. (Franklin)

um, which is, at first, a small, low, broad cone, whose top gradually rises and sharpens, as the force of the whirl increases. *At its upper end* it becomes visible, by the warm air brought up to the cooler region, where its moisture begins to be condensed into thick vapour, by the cold, and is seen first at A, the highest part, which being now cooled, condenses what rises next at B, which condenses that at C, and that condenses what is rising at D, the cold operating by the contact of the vapors faster in a right line downwards, than the vapours themselves can climb in a spiral line upwards; they climb, however, and as by continual addition they grow denser, and, concentrating currents that compose the whirl, they fly off, spread, and form a cloud.

"It seems easy to conceive, how, by this successive condensation from above, the spout appears to drop or descend from the cloud, though the materials of which it is composed are all the while ascending.

"The condensation of the moisture contained in so great a quantity of warm air as may be supposed to rise in a short time in this prodigiously rapid whirl, is, perhaps, sufficient to form a great extent of cloud, though the spout should be over land, as those at *Hatfield*; and if the land happens not to be very dusty, perhaps the lower part of the spout will scarce become visible at all; though the upper, or what is commonly called, the descending part, be very distinctly seen.

"The same may happen at sea, in case the whirl is not violent enough to make a high vacuum, and raise the column, &c. In such case, the upper part A B C D only will be visible, and the bush, perhaps, below.

"But if the whirl be strong, and there be much dust on the land, and the col-

umn W W be raised from the water, then the lower part becomes visible, and sometimes even united to the upper part. For the dust may be carried up in the spiral whirl, till it reach the region where the vapour is condensed, and rise with that even to the clouds: And the friction of the whirling air, on the sides of the column W W, may detach great quantities of its water, break it into drops, and carry them up in the spirial whirl mixed with the air; the heavier drops may, indeed, fly off, and fall, in a shower, round the spout; but much of it will be broken into vapour, yet visible; and thus, in both cases, by dust at land, and, by water at sea, the whole tube may be darkened and rendered visible.

"As the whirl weakens, the tube may (in appearance) separate in the middle, the column of water subsiding, and the superior condensed part drawing up the cloud. Yet still the tube, or whirl of air, may remain entire, the middle only becoming invisible, as not containing visible matter."

(a) Here we have the ring of the true philosopher: "Nothing, certainly, can be more improving to a searcher into nature than objections, judiciously made, to his opinion, taken up, perhaps, too hastily." Franklin welcomes the fair criticisms of the Boston Doctor.

(b) "I am so engaged in business, public and private." To all who are acquainted with the immense amount of work performed by Franklin, it is not surprising that he finds but comparatively little time for the more pleasing investigations of science. But it was then, as it is now, that it is the busiest man who finds time for all necessary work, and Franklin certainly found time in this case to prepare the most excellent scientific paper he sent to the Boston Doctor.

(c) Even if the vacuum were complete, the height of the column that is pressed inwards by the weight of the atmosphere could not greatly exceed thirty feet.

(d) "I must, however, no longer call it my hypothesis." A generous statement, since Stuart's explanation was certainly very obscure.

(e) Franklin is quite correct in this supposition. The whirlwind and the waterspout are the same phenomena, being due to the same causes, with, however, the difference that the whirlwind is produced by a whirling column of air passing over the land, while the waterspout is produced by this column passing over the water. Note here the clear and logical statement as to their resemblances.

(1) Both waterspouts and whirlwinds possess a progressive as well as a rotary or circular motion.

(2) Both waterspouts and whirlwinds occur after periods of great atmospheric heat, when the air has been free from winds.

(3) The wind blows in all directions from the extended space surrounding both water-spouts and whirlwinds directly towards the water-spout or the whirlwind.

(4) When waterspouts, by reason of their progressive motion, leave the sea and move over the land, they produce all the characteristic effects of whirlwinds, thus showing them to be the same.

(5) Both waterspouts and whirlwinds occur most commonly during the day time.

(f) Franklin now proceeds to apply his theory as regards the formation of waterspouts, producing for this purpose a plan and an elevation of the spout as he conceives it to be produced. He bases his theory on two assumptions, that all should be willing to admit; *i. e.*,—

(1) A higher temperature in the lower regions of the atmosphere than in the upper regions, and, consequently, a more rarefied condition near the surface of the earth than in the upper regions. Such a condition would, of course, necessitate an absence of wind.

(2) An exceedingly moist condition of the atmosphere.

Franklin then draws a picture of an extended area of land or sea, of, as he says, perhaps sixty miles square. Under conditions of prolonged calm, and with no clouds in the sky to prevent the sun's heat from freely reaching the earth's surface, these conditions perhaps continuing for several days, the lower strata of air become intensely heated. He then pictures the surrounding air as being relatively much colder, and as, therefore, remaining much heavier than that over the heated area. Under these circumstances, there would necessarily be produced a rising or ascending current of the lower air, accompanied by the descent of the colder and heavier air. But this rising does not immediately take place alike over all portions of the heated area. It begins over that portion of the area which is

the most highly heated, the remaining portion of the warm air flowing horizontally over all portions of the heated area towards this column. In this way, the whirl is formed pretty much as Franklin remarks, like the funnel-shaped depression produced in the surface of the water in a tub, that is discharging its water through a hole or opening in the bottom of the tub.

Franklin then points out the fact that since inflowing horizontal currents possess considerable motion, when they reach the central rising column, they are unable to suddenly change their direction to that of the vertical motion, so that they join the ascending column by means of a spiral motion.

Franklin then points out the fact that the velocity of the inflowing current will necessarily be greatest in those portions where the temperature of the air is greatest; *i. e.*, near the highly-heated surface. Consequently, it is here that the whirling motion is the swiftest, and, therefore, the vacuum must be greatest near the earth's surface, decreasing as the column rises.

(g) Fig. 10 is clear, and needs no explanation. The rising of the water from the surface of the sea is a natural result of the passage of the vacuous area.

(h) The whirling motion of the air is at first invisible, but forms a mass of clouds as soon as the moist air is condensed by the cold. It is for this reason that the spout may seem to drop or descend from the clouds, although the moisture of which it is formed has been continually ascending.

In addition to the valuable papers prepared by Franklin on geographical physics, to which we have already referred; *i. e.*, the paper as to the cause of thunder-storms, the aurora borealis and waterspouts, there yet remains to be discussed an observation of very great value respecting the cause of the great northeast storms of the United States. Since, as is now well known, the greater part of the work of the United States Weather Bureau as regards the preparation of forecasts of coming changes in the weather, is based on the peculiarities of the movements of our great northeast storms, it will readily be seen that this discovery of Franklin's should be ranked among the most important of his researches in geographical physics. While from a popular standpoint, this matter is not so attract-

ive as his demonstration of the identity of disruptive electric discharges and lightning, yet from a scientific standpoint, it should contribute to his merited reputation as a philosopher, as much, if not more, that his famous kite experiment. Then, too, from a practical standpoint, while it might seem that the invention of the lightning rod was of more direct benefit to mankind, yet the saving of life and property that would frequently result from the timely warning of the approach of a dangerous northeast storm would probably be immensely greater than would ever be possible by protection afforded by lightning rods.

Franklin informs us just how he came to think of the causes of the great northeast storms in this country as starting in an area of low barometer somewhere in the west and progressing generally towards the northeast. It appears that an eclipse of the moon was to be visible at Philadelphia on a certain Friday at 9 P. M. Franklin made preparation for the proper observing of this eclipse, but, unfortunately, that night a storm visited Philadelphia, approaching the city from the northeast, and continuing violently all that night and the next day, prevented any observations of the eclipse from being made. To Franklin's great astonishment, the newspapers contained an account of the fact that this eclipse had been observed in the city of Boston. Since this storm apparently approached the city of Philadelphia from the northeast, it would seem that it should have reached Boston before it reached Philadelphia, Boston being, as is well known, northeast of the city of Philadelphia. Writing to his brother, who lived in the city of Boston, he ascertained the fact that the eclipse was over at least one hour before the storm commenced. This caused Franklin to make further inquiries, when he found that, as a rule, the great northeast storms of this country begin to the leeward; *i. e.*, start somewhere to the southwest, then moving in a general northeast path across the country.

In a letter to the Rev. Jared Eliot, dated Philadelphia, July 16, 1747, Franklin says:

"We have freqently, along this North American coast, storms from the northeast, which blow violently sometimes three or four days. Of these I have had a very singular opinion some years, viz., that, though the course

of the wind is from northeast to southwest, yet the course of the storm is from southwest to northeast; that is, the air is in violent motion in Virginia before it moves in Connecticut, and in Connecticut before it moves at Cape Sable, &c. My reasons for this opinion, (if the like have not occurred to you,) I will give in my next."

In another letter to the same gentleman, dated Philadelphia, February 13, 1749-50 (year uncertain), he fulfills the promise referred to in the preceding letter, and at fairly full length regarding his views of the motion of the northeast storms:

"You desire to know my thoughts about the northeast storms beginning to leeward. Some years since, there was an eclipse of the moon at nine o'clock in the evening, which I intended to observe: but before night a storm blew up at the northeast, and continued violent all night and all next day; the sky thick-clouded, dark and rainy, so that neither moon nor stars could be seen. The storm did a great deal of damage all along the coast, for we had accounts of it in the newspapers from Boston, Newport, New York, Maryland, and Virginia; but what surprised me was, to find in the Boston newspapers an account of an observation of that eclipse made there; for I thought, as the storm came from the northeast, it must have begun sooner at Boston than with us, and consequently have prevented such observation. I wrote to my brother about it, and he informed me, that the eclipse was over there an hour before the storm began. Since which I have made inquiries from time to time of travellers, and of my correspondents northeastward and southwestward, and observed the accounts in the newspapers from New England, New York, Maryland, Virginia, and South Carolina; and I find it to be a constant fact, that northeast storms begin to leeward; and are often more violent there than farther to windward. Thus the last October storm, which with you was on the 8th, began on the 7th in Virginia and North Carolina, and was most violent there.

"As to the reason of this, I can only give you my conjectures. Suppose a great tract of country, land and sea, to wit, Florida and the Bay of Mexico, to have clear weather for several days, and to be heated by the sun, and its air thereby exceedingly rarefied. Suppose the country northeastward, as Pennsylvania, New England, Nova Scotia, and Newfoundland, to be at the same time covered with clouds, and its air chilled and condensed. The rarefied air being lighter must rise, and the denser air next to it will press into its place; that will be followed by the next denser air, that by the next, and so on. Thus, when I have a fire in my chimney, there is a current of air constantly flowing from the door to the chimney; but the beginning of the motion was at the chimney, where the air being rarefied by the fire rising, its place was supplied by the cooler air that was next to it, and the place of that by the next, and so on to the door. So the water in a long sluice or mill-race, being stopped by a gate at one end, to let it out, the water next the gate begins first to move, that which is next to it

follows; and so, though the water proceeds forward to the gate, the motion which began there runs backwards, if one may so speak, to the upper end of the race, where the water is last in motion. We have on this continent a long ridge of mountains running from northeast to southwest; and the coast runs the same course. These may contribute towards the direction of the winds, or at least influence them in some degree. If these conjectures do not satisfy you, I wish to have yours on the subject."

At a later date; *i. e.*, May 12, 1760, in a letter to Alexander Small, of London, Franklin writes as follows:

"Agreeable to your request, I send you my reasons for thinking that our North-East storms in North America begin first, in point of time, in the South-West parts: That is to say, the air in Georgia, the farthest of our colonies to the South-West, begins to move South-Westerly before the air of Carolina, which is the next colony North-Eastward; the air of Carolina has the same motion before the air of Virginia, which lies still more North-Eastward; and so on North-Easterly through Pennsylvania, New York, New England, &c., quite to Newfoundland.

"These North-East storms are generally very violent, continue sometimes two or three days, and often do considerable damage in the harbours along the coast. They are attended with thick clouds and rain.

"What first gave me this idea, was the following circumstance. About twenty years ago, a few more or less, I cannot from my memory be certain, we were to have an eclipse of the moon at Philadelphia, on a Friday evening, about nine o'clock. I intended to observe it, but was prevented by a North-East storm, which came on about seven with thick clouds as usual, that quite obscured the whole hemisphere. Yet when the post brought us the Boston newspaper, giving an account of the effects of the storm in those parts, I found the beginning of the eclipse had been well observed there, though Boston lies N. E. of Philadelphia about 400 miles. This puzzled me, because the storm began with us so soon as to prevent any observation, and being a N. E. storm, I imagined it must have began rather sooner in places farther to the North Eastward, than it did at Philadelphia. I therefore mentioned it in a letter to my broher, who lived in Boson; and he informed me that the storm did begin with them till near eleven o'clock, so that they had a good observation of the eclipse: and upon comparing all the other accounts I received from the several colonies, of the time beginning of the same storm and since that of other storms of the same kind, I found the beginning to be always later the farther North-Eastward. I have not my notes with me here in England, and cannot from memory, say the proportion of time to distance, but I think it is about an hour to every hundred miles.

"From thence I formed an idea of the cause of these storms, which I would explain by a familiar instance or two. * * * Suppose a long canal of water stopp'd at the end of a gate. The water is quite at rest till the gate is open, then it begins to move out through the gate; the water next the gate is first in motion, and moves towards the gate; the water next to

that first water moves next, and so on successively, till the water at the head of the canal is in motion, which is last of all. In this case all the water moves indeed towards the gate, but the successive times of beginning motion are the contrary way, viz. from the gate backwards to the head of the canal. Again, suppose the air in a chamber at rest, no current through the room till you make a fire in the chimney. Immediately the air in the chimney being rarefied by the fire, rises; the air next the chimney flows in to supply its place, moving towards the chimney; and, in consequence, the rest of the air successively, quite back to the door. Thus to produce our North-East storms, I suppose some great heat and rarefaction of air in or about the Gulph of Mexico; the air thence rising has its place supplied by the next more northern, cooler, and therefore denser and heavier, air; that, being in motion, is followed by the next more northern air, &c., &c., in a successive current, to which current our coast and inland ridge of mountains give the direction of North-East, as they lie N. E. and S. W.

"This I offer only as an hypothesis to account for this particular fact; and, perhaps, on farther examination, a better and truer may be found. I do not suppose all storms generated in the same manner. Our North-West thunder-gust in America I know are not; but of them I have written my opinion fully in a paper which you have seen."

While unfortunately Franklin did not in this, as in many other of his papers, give the exact date of the eclipse, yet, since this date fixes the time when his attention was first directed to the fact that the northeast storms of this country start in the southwest, Prof. Bache, of the University of Pennsylvania, by means of a careful study of all the eclipses of the moon known to have occurred at about this time, has definitely fixed the date at October 21, 1743. This is a matter of no little scientific importance, since a claim has been made that the law of the movements of the northeast storms of the United States was first published by another before the time referred to in the letter to Eliot. It seems from this fact, therefore, that Franklin was the first discoverer of the important facts concerning the movements of the northeast storms.

There remains yet another important subject in geographical physics that attracted Franklin's attention at a comparatively early date. I allude to the existence and causes of that great moving mass of heated water off the eastern coast of the United States, known as the Gulf Stream. He gives an account of this stream in a letter to David Leroy, at Paris, the letter bearing date of August, 1785:

"Vessels are sometimes retarded, and sometimes forwarded in their

voyages, by currents at sea, which are often not perceived. (a) About the year 1769 or 1670, there was an application made by the Board of Customs at Boston, to the Lords of the Treasury in London, complaining that the packets between Falmouth and New York were generally a fortnight longer in their passages, than merchant ships from London to Rhode Island, and proposing that for the future they should be ordered to Rhode Island instead of New York. Being then concerned in the management of the American post-office, I happened to be consulted on the occasion; and it appearing strange to me, that there should be such a difference between two places scarce a day's run asunder, especially when the merchant ships are generally deeper laden, and more weakly manned than the packets, and had from London the whole length of the river and channel to run before they left the land of England, while the packets had only to go from Falmouth, I could not but think the fact misunderstood or misrepresented. (b) There happened then to be in London a Nantucket sea captain of my acquaintance, to whom I communicated the affair. He told me he believed the fact might be true; but the differenee was owing to this, that the Rhode Island captains were acquainted with the Gulf Stream, which those of the English packets were not. 'We are well acquainted with that stream,' says he, 'because in our pursuit of whales, which keep near the sides of it, but are not to be met with in it, we run down along the sides, and frequently cross it to change our sides; and in crossing it have sometimes met and spoke with those packets, who were in the middle of it, and stemming it. We have informed them that they were stemming a current that was against them to the value of three miles an hour; and advised them to cross it and get out of it; but they were too wise to be counselled by simple American fishermen. When the winds are but light,' he added, 'they are carried back by the current more than they are forwarded by the wind; and, if the wind be good, the subtraction of seventy miles a day from their course is of some importance.' (c) I then observed it was a pity no notice was taken of this current upon the charts, and requested him to mark it out for me, which he readily complied with, adding directions for avoiding it in sailing from Europe to North America. I procured it to be engraved by order from the general post-office, on the old chart of the Atlantic, at Mount and Page's, Tower Hill; and copies were sent down to Falmouth for the captains of the packets, who slighted it however; but it is since printed in France, of which edition I hereto annex a copy. (See Fig. 12.)

(d) "This stream is probably generated by the great accumulation of water on the eastern coast of America between the tropics, by the trade winds which constantly blow there. It is known, that a large piece of water ten miles broad and generally only three feet deep, has by a strong wind had its waters driven to one side and sustained so as to become six feet deep, while the windward side was laid dry. This may give some idea of the quantity heaped up on the American coast, and the reason of its running down in a strong current through the islands into the Bay of Mexico, and from thence issuing through the Gulf of Florida, and proceeding along the coast to the banks of Newfoundland, where it turns off towards and runs down through the Western Islands. Having since crossed this stream

several times in passing between America and Europe, I have been attentive to sundry circumstances relating to it, by which to know when one is in it; and besides the gulf weed with which it is interspersed, I find that it is always warmer than the sea on each side of it, and that it does not sparkle in the night. (e) I annex hereto the observations made with the thermometer in two voyages, and possibly may add a third. It will appear from them, that the thermometer may be a useful instrument to a navigator, since currents coming from the northward into southern seas will probably be found colder than the water of those seas, as the currents from the southern seas into the northern are found warmer. And it is not to be wondered, that so fast a body of deep warm water, several leagues wide,

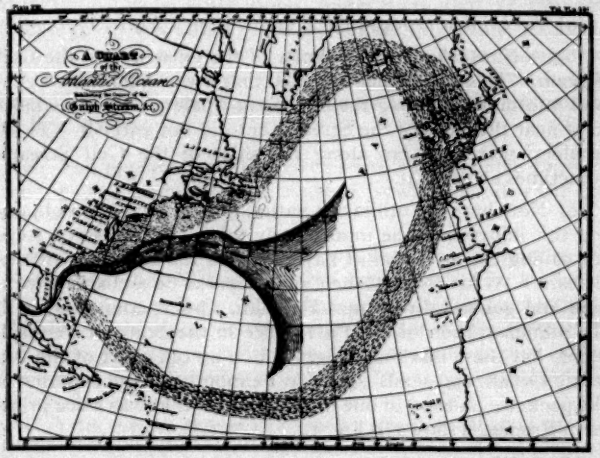


Fig. 12. Franklin's Early Chart of the Gulf Stream.

coming from between the tropics and issuing out of the gulf into the northern seas should retain its warmth longer than the twenty or thirty days required to its passing the banks of Newfoundland. The quantity is too great, and it is too deep to be suddenly cooled by passing under a cooler air. (f) The air immediately over it, however, may receive so much warmth from it as to be rarefied and rise, being rendered lighter than the air on each side of the stream; hence those airs must flow in to supply the place of the rising warm air, and, meeting with each other, form those tornadoes and waterspouts frequently met with, and seen near and over the stream; and as the vapor from a cup of tea in a warm room, and the breath of an animal in the same room, are hardly visible, but become sensible immediately when out in the cold air, so the vapor from the Gulf Stream, in

warm latitudes, is scarcely visible, but when it comes into the cool air from Newfoundland, it is condensed into the fogs, for which those parts are so remarkable.

"The power of wind to raise water above its common level in the sea is known to us in America, by the high tides occasioned in all our seaports when a strong northeaster blows against the Gulf Stream.

"The conclusion from these remarks is, that a vessel from Europe to North America may shorten her passage by avoiding to stem the stream, in which the thermometer will be very useful; and a vessel from America to Europe may do the same by the same means of keeping in it. It may have often happened accidentally, that voyages have been shortened by these circumstances. It is well to have the command of them."

(a) An evident typographical error, from 1769 to 1770.

(b) A Nantucket Captain knew of the existence of the Gulf Stream. This old seaman asserted that it was a matter of general information among the American whalers that the whales kept near the sides of the Stream, but did not enter it. These whalers, therefore, ran along the sides of the Gulf Stream, sometimes crossing it.

(c) Note here the utilitarian nature of Franklin. On obtaining this information he immediately takes the necessary steps for calling the attention of navigators to the existence of this Stream. At his request, the Captain marks on a chart its location and general direction. Franklin, who is connected with the administration of the Post Office in the State of Pennsylvania, has these markings engraved on an old chart of the Atlantic Ocean, and sends copies to Falmouth for the captains of the packets. A copy of one of these charts that was since printed in France, is shown in Fig. 12.

(d) Bearing in mind the time that this paper was written, Franklin's explanation as to the causes of the Gulf Stream may be regarded as excellent.

(e) Note here Franklin's practical use of the thermometer in mapping out the position of the boundaries of the Gulf Stream, as well as his valuable suggestions as to the aid the thermometer is capable of affording navigators in such cases. Franklin published an account of measurements of the temperature of the Gulf Stream made during a subsequent voyage, while on the Pennsylvania Packet, Captain Osborne, from London to Philadelphia, in April and May, 1775. During these meas-

urements, some interesting observations were made as to deep sea temperatures. In one instance, during perfectly calm weather an empty bottle, tightly corked, was sent down to the depth of some twenty fathoms. On drawing it up, it was still found to be empty. When again let down to a depth of thirty-five fathoms, the pressure of the water had been sufficiently great to force the cork into the bottle, so that when the bottle was drawn to the surface it was found to be filled with water at a temperature six degrees colder than that at the surface. In a somewhat similar manner, experiments made with an empty cask showed that, although some leakage occurred during the drawing up of the cask, the water it contained was at a temperature of some 12 degrees colder than the surface water.

(f) The explanation here given as to the probable cause of the fogs so common off the coast of Newfoundland is the one that is still generally held.

It was during one of the many voyages between America and Europe that Franklin invented an important device known as the swimming anchor. This device is of use in preventing a ship from driving to leeward in deep water, where there is no sounding, and where, consequently, an ordinary anchor cannot be employed. Franklin names the following characteristics which should be possessed by this type of anchor:

(1) Its surface should be of such a size that, when at the end of the hawser in the water, and placed perpendicularly, it should so hold as to bring the ship's head to the wind, in which situation the wind has least power to drive the vessel.

(2) It should be able, by its resistance, to prevent the ship's receiving way.

(3) It should be capable of being placed below the heave of the sea, but not below the undertow.

(4) It should not take up much room in the ship.

(5) It should be capable of being easily thrown into the water and assuming therein its desired position, and should afterwards be easy to take into the ship and stow away.

Franklin devised two of these anchors. One of them was made in the form of a kite, Fig. 13, while the other had the

shape of an umbrella. Franklin thus describes the umbrella type of anchor:

"The other machine for the same purpose is to be made more in the form of an umbrella, as represented in figure 14. The stem of the umbrella, a square spar of proper length, with four movable arms, of which two are represented C, C, figure 14. These arms to be fixed in four joint cleats, as D, D, &c., one on each side of the spar, but so as that the four arms may open by turning on a pin in the joint. When open they form a cross on which a four-square canvass sail is to be extended, its corners fastened to the ends of the four arms. Those ends are also to be stayed by ropes fastened to the stem or spar, so as to keep them short of being at right angles with it; and to the end of one of the arms should be hung the small

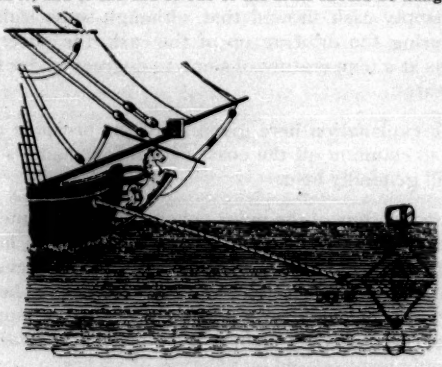


Fig. 13. Franklin's Swimming Anchor.

bag of ballast, and to the end of the opposite arm the empty keg. This, on being thrown into the sea, would immediately open; and when it had performed its function, and the storm over, a small rope from its other end being pulled on, would turn it, close it, and draw it easily home to the ship. This machine seems more simple in its operation, and more easily manageable than the first, and perhaps may be as effectual."

Another important invention belonging to applied physics is to be found in what is known as Franklin's Pennsylvania Fire-Place. The following description is given by Franklin:

"An Account
of the New-Invented
Pennsylvanian Fire-Place;
wherein
Their construction and manner of operation is particularly explained; their

advantages above every other method of warming rooms demonstrated; and all objections that have been raised against the use of them answered and obviated. With directions for putting them up, and for using to the best advantage. And a copper-plate, in which the several parts of the machine are exactly laid down, from a scale of equal parts.

Philadelphia;
Printed and sold by B. Franklin, 1744."

* * * * * * *

"In these Northern Colonies the inhabitants keep fires to sit by, generally seven months in the year; that is, from the beginning of October, to the end of April; and, some winters, near eight months, by taking in part of September and May.

"Wood, our common fuel, which within these hundred years might be had at every man's door, must now be fetched near one hundred miles to some towns, and makes a very considerable article in the expence of families.

"As therefore so much of the comfort and conveniency of our lives,

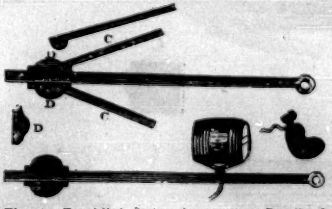


Fig. 14. Franklin's Swimming Anchor, Details of.

for so great a part of the year, depends on the article of fire; since fuel is become so expensive, and (as the country is more cleared and settled) will of course grow scarcer and dearer, any new proposal for saving the wood, and for lessening the charge, and augmenting the benefit of fire by some particular method of making and managing it, may at least be thought worth consideration.

* * * * * * *

"To avoid the several inconveniences, and at the same time retain all the advantages of other fire-places, was contrived the Pennsylvania Fire-Place, now to be described.

"This machine consists of

"A bottom plate (i) (See Plate annexed, figure 15.)

"A back plate, (ii)

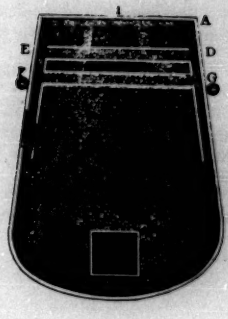
"Two side plates, (iii iii)

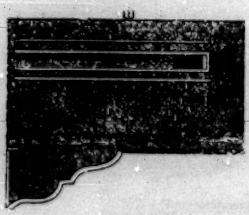
"Two middle plates, (iv iv) which joined together, form a tight box, with winding passages in it for warming the air.

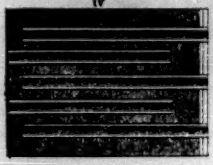
"A front plate, (v)

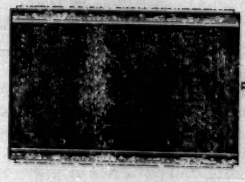
"A top plate, (vi)

"These are all cast of iron, with mouldings or ledges where the plates









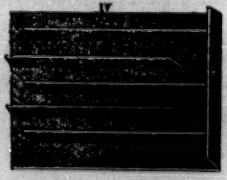
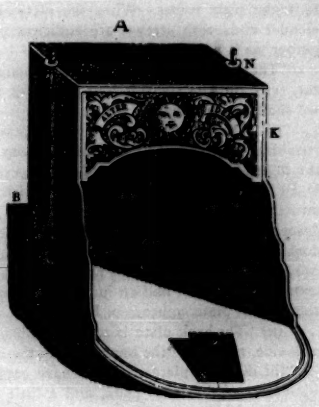
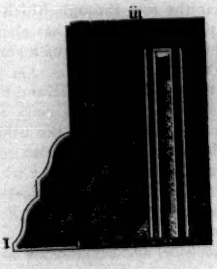
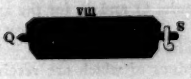


Fig.15. The Pennsylvania







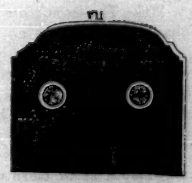


Plate 8. Joint of the proper size.

Fire-place.

come together, to hold them fast, and retain the mortar used for pointing to make tight joints. When the plates are all in their places, a pair of slender rods with screws, are sufficient to bind the whole very firmly together, as it appears in A.

"There are, moreover, two thin plates of wrought iron, viz.: the sutter, (vii) and the register, (viii); besides the screw-rods O P, all of which we shall explain in their order.

"(i) The bottom plate or hearth-piece, is round before, with a rising moulding that serves as a fender to keep coals and ashes from coming to the floor, &c. It has two ears, F G, perforated to receive the screw-rods O P: a long air-hole, a a, through which the fresh outward air passes up into the air-box; and three smoke-holes B C through which the smoke descends and passes away; all represented by dark squares. It has also double ledges to receive between them the bottom edges of the plate, the two side plates and the two middle plates. These ledges are about an inch asunder, and about half an inch high; a profile of two of them joined to a fragment of plate, appears in B.

"(ii) The back plate is without holes, having only a pair of ledges on each side, to receive the back edge of the two.

"(iii iii) Side plates: These have each a pair of ledges to receive the side-edges of the front plate, and a little shoulder for it to rest on; also two pair of ledges to receive the side edges of the two middle plates which form the air-box; and an oblong air-hole near the top, through which is discharged into the room the air warmed in the air-box. Each has also a wing or bracket, H and I, to keep in falling brands, coals, &c., and a small hole, Q and R, for the axis of the register to turn in.

"(iv iv) The air-box is composed of the two middle plates DE and FG. The first has five thin ledges or partitions cast on it, two inches deep, the edges of which are received in so many pair of ledges cast in the other. The tops of all the cavities formed by these thin deep ledges, are also covered by a ledge of the same form and depth, cast with them; so that when the plates are put together and the joints luted, there is no communication bewtween the air-box and the smoke. In the winding passages of this box, fresh air is warm'd as it passes into the room.

"(v) The front plate is arched on the under side, and ornamented with foliages, &c. It has no ledges.

"(vi) The top plate has a pair of ears, M N, answerable to those in the bottom plate, and perforated for the same purpose: It has also a pair of ledges running round the under side, to receive the top edges of the front, back, and side plates. The air-box does not reach up to the top plate by two inches and half.

"(vii) The shutter is of thin wrought iron and light, of such a length and breadth as to close well the opening of the fire-place. It is used to blow up the fire, and to shut up and secure it at nights. It has two brass knobs for handles, *d d*, and commonly slides up and down in a groove, left in putting up the fire-place, between the foremost ledge of the side-plates, and the face of the front plate; but some chuse to set it aside when it is not in use, and apply it on occasion.

"(viii) The register is also of thin wrought iron. It is placed between the back plate and air-box, and can, by means of the key S, be turned on its axis, so as to lie in any position between level and upright.

"The screw-rods O P are of wrought iron, about a third of an inch thick, with a button at bottom, and a screw and nut at top, and may be ornamented with two small brasses screwed on above the nuts.

"To put this Machine to work,

"1. A false back of four inch (or, in shallow small chimneys, two inch) brick work is to be made in the chimney, four inches or more from the true back: From the top of this false back a closing is to be made over to the breast of the chimney, that no air may pass into the chimney, but what goes under the false back, and up behind it.

"2. Some bricks of the hearth are to be taken up, to form a hollow under the bottom plate across which hollow runs a thin tight partition, to keep apart the air entering the hollow and the smoke; and is therefore placed between the air-hole and smoke-holes.

"3. A passage is made, communicating with the outer air, to introduce that air into the fore part of the hollow under the bottom-plate, whence it may rise thro' the air-hole into the air-box.

"4. A passage is made from the back part of the hollow, communicating with the flue behind the false back: Through this passage the smoke is to pass.

"The fire-place is to be erected upon these hollows, by putting all the plates in their places, and screwing them together.

"Its operation may be conceived by observing the plate entitled, *Profile of the Chimney and Fire-place.* (Fig. 16.)

"M The mantel-piece or breast of the chimney.

"C The funnel.

"B The false back and closing.

"E True back of the chimney.

"T Top of the fire-place.

"F The front of it.

"A The place where the fire is made.

"D The air-box.

"K The hole in the side plate, through which the warmed air is discharged out of the air-box into the room.

"H The hollow filled with fresh air, entering at the passage I, and ascending into the air-box through the air-hole in the bottom plate, near

"G The partition in the hollow to keep the air and smoke apart.

"P The passage under the false back and part of the hearth for the smoke.

"The arrows show the course of the smoke.

"The fire being made at A, the flame and smoke will ascend and strike the top T, which will thereby receive a considerable heat. The smoke, finding no passage upwards, turns over the top of the air-box, and descends between it and the back plate to the holes at B, in the bottom plate, heating, as it passes, both plates of the air-box, and the said back-plate; the front plate, bottom and side plates, are also all heated at the same time.

The smoke proceeds in the passage that leads it under and behind the false back, and so rises into the chimney. The air of the room, warmed behind the back plate, and by the sides, front, and top plates, becoming specifically lighter than the other air in the room, is obliged to rise; but the closure over the fire-place hindering it from going up the chimney, it is forced out into the room, rises by the mantle-piece to the ceiling, and spreads all over the top of the room, whence, being crouded down gradually by the stream newly-warm'd air that follows and rises above it, the whole room becomes in a short time equally warmed.

"At the same time the air, warmed under the bottom-plate, and in the

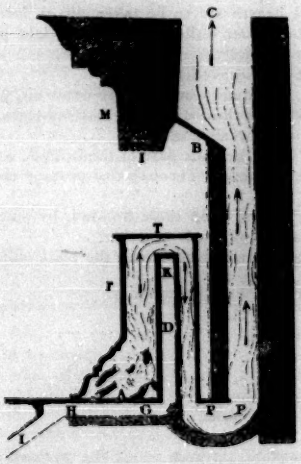


Fig. 16. Profile of the Pennsylvania Chimney and Fire Place.

air-box, rises and comes out of the holes in the side-plates, very swiftly if the door of the room be shut, and joins its current with the stream before mentioned, rising from the side, back, and top plates.

"The air that enters the room through the air-box is fresh, though warm; and, computing the swiftness of its motion with the areas of the holes, it is found that near ten barrels of fresh air are hourly introduced by the air-box; and by this means the air in the room is continually changed, and kept, at the same time, sweet and warm.

"It is to be observed, that the entering air will not be warm at first lighting the fire, but heats gradually, as the fire increases.

"A square opening for a trap-door should be left in the closing of the chimney, for the sweeper to go up: The door may be made of slate or tin,

and commonly kept close shut, but so placed as that turning up against the back of the chimney when open, it closes the vacancy behind the false back, and shoots the soot, that falls in sweeping, out upon the hearth. This trap-door is a very convenient thing.

"In rooms where much smoking of tobacco is used, it is also convenient to have a small hole, about five or six inches square, cut near the ceiling through into the funnel: This hole must have a shutter, by which it may be clos'd or open'd at pleasure. When open, there will be a strong draught of air thro' it into the chimney, which will presently carry off a cloud of smoke, and keep the room clear: If the room be too hot likewise, it will carry off as much of the warm air as you please, and then you may stop it entirely, or in part, as you think fit. By this means it is, that the tobacco smoke does not descend among the heads of the company near the fire, as it must do before it can get into common chimneys. ?

"THE MANNER OF USING THIS FIRE-PLACE.

"Your cord-wood must be cut into three lengths; or else a short piece, fit for the fire-place, cut off, and the longer left for the kitchen or other fires. Dry hickory, or ash, or any woods that burn with a clear flame are rather to be chosen, because such are less apt to foul the smoke-passages with soot; and flame communicates with its light, as well as by contact, greater heat to the plates and room. But where more ordinary wood is used, half a dry faggot of brush-wood, burnt at the first making of fire in the morning is very advantageous, as it immediately, by its sudden blaze, heats the plates and warms the room (which with bad wood slowly kindling would not be done so soon) and at the same time, by the length of its flame, turning in the passages, consumes and cleanses away the soot that such bad smoky wood had produced therein the preceding day, and so keeps them always free and clean.—When you have laid a little back log, and placed your billets on small dogs, as in common chimneys, and put some fire to them, then slide down your shutter as low as the dogs, and the opening being by that means contracted, the air rushes in briskly, and presently blows up the flames. When the fire is sufficiently kindled, slide it up again. In some of these fire-places there is a little six-inch square trap-door of thin wrought iron or brass, covering a hole of like dimensions near the fore-part of the bottom-plate, which being by a ring lifted up towards the fire, about an inch, where it will be retained by two springing sides fixed to it perpendicularly, (See fig. 16, C, as above), the air rushes in from the hollow under the bottom plate, and blows the fire. Where this is used, the shutter serves only to close the fire at nights. The more forward you can make your fire on the hearth-plate, not to be incommoded by the smoke, the sooner and more will the room be warmed. At night when you go to bed, cover the coal or brands with ashes, as usual; then take away the dogs, and slide down the shutter close to the bottom-plate, sweeping a little ashes against it, that no air may pass under it; then turn the register, so as very near to stop the flue behind. If no smoke then comes out at crevices into the room, it is right: If any smoke is

perceived to come out, move the register so as to give a little draft, and it will go the right way. Thus the room will be kept warm all night; for the chimney being almost entirely stopt, very little cold air, if any, will enter the room at any crevice. When you come to re-kindle the fire in the morning, turn open the register before you lift up the slider, otherwise, if there be any smoke in the fire-place, it will come out into the room. By the same use of the shutter and register, a blazing fire may be presently stifled as well as secured, when you have occasion to leave it for any time: and at your return you will find the brands warm, and ready for a speedy re-kindling. The shutter alone will not stifle a fire, for it cannot well be made to fit so exactly but that air will enter, and that in a violent stream, so as to blow up and keep alive the flames, and consume the wood, if the draught be not checked by turning the register to shut the flue behind The register has also two other uses. If you observe the draught of air into your fire-place to be stronger than is necessary, (as in extreme cold weather it often is), so that the wood is consumed faster than usual; in that case, a quarter, half, or two-thirds turn of the register will check the violence of the draught, and let your fire burn with the moderation you desire: And at the same time both the fire-place and the room will be warmer, because less cold air will enter and pass through them. And if the chimney should happen to take fire, which indeed there is very little danger of, if the preceding directions be observed in making fires, and it be well swept once a year; for, much less wood being burnt, less soot is proportionately made; and the fuel being blown into flame by the shutter (or the trap door bellows) there is consequently less smoke from the fuel to make soot; then, though the funnel should be foul, yet the sparks have such a crooked up and down round about way to go, that they are out before they get at it. I say, if ever it should be on fire, a turn of the register shuts all close, and prevents any air going into the chimney, and so the fire may be easily stifled and mastered."

THE ADVANTAGES OF THIS FIRE-PLACE.

"Its advantages above the common fire-places are,

"1. That your whole room is equally warmed, so that people need not close round the fire, but may sit near the window, and have the benefit of the light for reading, writing, needlework, etc. They may sit with comfort in any part of the room, which is a very considerable advantage in a large family, where there must often be two fires kept, because all cannot conveniently come at one.

"2. If you sit near the fire, you have not that cold draft of uncomfortable air nipping your back and heels, as when before common fires, by which you may catch cold, being scorched before, and, as it were, froze behind.

"3. If you sit against a crevice, there is not that sharp draft of cold air playing on you, as in rooms where there are fires in the common way; by which many catch cold, whence proceed coughs, catarrhs, tooth-aches, fevers, pleurisies, and many other diseases.

"4. In case of sickness, they make most excellent nursing-rooms; as they constantly supply a sufficiency of fresh air, so warmed at the same time as to be no way inconvenient or dangerous. A small one does well in a chamber; and, the chimneys being fitted for it, it may be removed from one room to another, as occasion requires, and fixed in half an hour. The equal temper, too, and warmth of the air of the room is thought to be particularly advantageous in some distempers; for it was observed in the winters of 1730 and 1736, when the small-pox spread in Pennsylvania, that very few children of the Germans died of that distemper in proportion to those of the English; which was ascribed, by some, to the warmth and equal temper in their stove rooms, which made the disease as favorable as it commonly is in the West Indies. But this conjecture we submit to the judgment of physicians.

"5. In common chimneys, the strongest heat from the fire, which is upwards, goes directly up the chimney, and is lost; and there is such a strong draft into the chimney, that not only the upright heat, but also the back, sides, and downward heats are carried up the chimney by that draft of air; and the warmth given before the fire, by the rays that strike out towards the room, is continually driven back, crowded into the chimney, and carried up by the same draft of air. But here the upright heat strikes and heats the top plate, which warms the air above it, and that comes into the room. The heat likewise, which the fire communicates to the sides, back, bottom, and air-box, is all brought into the room, for you will find a constant amount of warm air coming out of the chimney corner into the room. Hold a candle just under the mantle-piece, or breast of your chimney, and you will see the flame bend outwards; by laying a piece of smoking paper on the hearth, on either side, you may see how the current of air moves, and where it tends, for it will turn and carry the smoke with it.

"6. Thus, as very little of the heat is lost, when this fire-place is used, *much less wood* will serve you, which is a considerable advantage where wood is dear.

"7. When you burn candles near this fire-place, you will find that the flame burns quite upright, and does not blare and run the tallow down, by drawing towards the chimney, as against common fires.

"8. This fire-place cures most smoky chimneys, and thereby preserves both the eyes and furniture.

"9. It prevents the fouling of chimneys; much of the lint and dust that contributes to foul a chimney being, by the low arch, obliged to pass through the flame, where it is consumed. Then, less wood being burnt, there is less smoke made. Again, the shutter, or trap-bellows, soon blowing the wood into a flame, the same wood does not yield so much smoke as if burnt in a common chimney; for, as soon as the flame begins, smoke in proportion ceases.

"10. And, if a chimney should be foul, it is much less likely to take fire. If it should take fire, it is easily stifled and extinguished.

"11. A fire may be very speedily made in this fire-place by the help of the shutter, or trap-bellows, as aforesaid.

"12. A fire may be soon extinguished by closing it with the shutter before, and turning the register behind, which will stifle it, and the brands will remain ready to rekindle.

"13. The room being once warm, the warmth may be retained in it all night.

"14. And lastly, the fire is so secured at night, that not one spark can fly out into the room to do damage.

"With all these conveniences, you do not lose the pleasing sight nor use of the fire, as in the Dutch ovens, but may boil the tea kettle, warm the flat irons, heat heaters, keep warm a dish of victuals by setting it on the top, etc.

Concerning the operation of the Pennsylvania Fire-Place, Franklin remarks:

"Having in 1742, invented an open stove for the better warming of rooms, and at the same time saving fuel, as the fresh air admitted was warmed in entering, I made a present of the model to Mr. Robert Grace, one of my early friends, who, having an iron furnace, found the casting of the plates for these stoves a profitable thing, as they were growing in demand. To promote that demand, I wrote and published a pamphlet, intitled "An Account of the new-invented Pennsylvania Fire-Places," &c. This pamphlet had a good effect. Governor Thomas was so pleased with the construction of this stove, as described in it, that he offered to give me a patent for the sole vending of them for a term of years; but I declined it from a principle, which has ever weighed with me on such occasions, viz: *That, as we enjoy great advantages from the inventions of others, we should be glad of an opportunity to serve others by any invention of ours; and this we should do freely and generously.*

"An ironmonger in London, however, assuming a good deal of my pamphlet, and working it up into his own, and making some small changes in the machine, which rather hurt its operation, got a patent for it there, and made, as I was told, a little fortune by it. And this is not the only instance of patents taken out of my inventions by others, though not always with the same success; which I never contested, as having no desire of profiting by patents myself, and hating disputes. The use of these fire-places in very many houses, both here and in Pennsylvania, and the neighboring states, has been, and is, a great saving of wood to the inhabitants."

In connection with his invention of stoves, Franklin gave considerable attention to the construction of chimneys. In a letter to John Ingenhousz, at Vienna, August 28, 1785, Franklin describes at length the different ways in which chimneys may be caused to smoke, and also points out the means by which this smoking may best be avoided.

It will be impracticable, on account of lack of space, to discuss this letter at length. It will suffice if some of the more

important of the causes of smoky chimneys are pointed out. These are given by Franklin as follows:

(1) Smoky chimneys are frequently produced in new houses by the mere want of air.

(2) Smoky chimneys are frequently caused by the opening into the room being too large; that is, too wide, too high, or both.

(3) Smoky chimneys may be caused by too short a chimney funnel. This happens necessarily where a chimney is required in a low building, since, if the funnel is raised high above the roof in order to strengthen the draught, it is in danger of being blown down.

(4) Smoky chimneys may be caused by one chimney overpowering another, where, for example, two chimneys exist in one large room and fires are made in both, the doors and windows being shut, the greater and stronger fire will overpower the weaker, drawing the air down its funnel to supply its demands, while air descending the funnel connected with the weaker fire will drive its smoke into the room.

(5) Smoky chimneys may also be caused by the tops of the chimneys being commanded by higher buildings, or by a hill, so that the wind, blowing over such eminences, falls like water over a dam, thus beating the smoke down the chimney.

(6) Smoky chimneys are sometimes caused by the chimney being lower than the top of a near-by house, the wind being deflected from the house and forced down the chimney.

Other causes are given, but these are the most important.

At a later date, Franklin describes another form of stove suitable for burning pit coal. In this form of stove the construction is such that the smoke itself is consumed. A paper describing this stove was read before the American Philosophical Society on the 28th of January, 1786. As will be seen, this stove is based on the principle of an inverted draught down through the burning material:

"Towards the end of the last century, an ingenious French philosopher, whose name I am sorry I cannot recollect, exhibited an experiment to show, that very offensive things might be burnt in the middle of a chamber, such as woolen rags, feathers, &c., without creating the least smoke or smell. The machine in which it was made, if I remember right, was of this form, (Plate XV, Fig. 17, No. 1), made of plate iron. Some clear

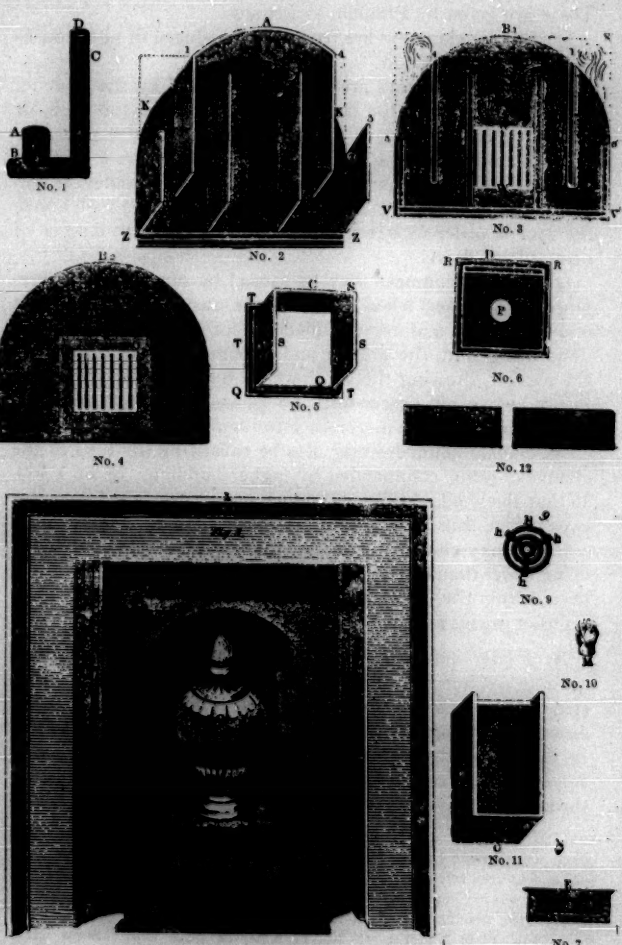


Fig. 17. Details of the Pennsylvania Fire-place.

burning charcoals were put into the opening of the short tube A, and supported there by the grate B. The air, as soon as the tubes grew warm, would ascend in the longer leg C, and go out at D, consequently air must enter at A, descending to B. In this course it must be heated by the burning coals through which it passed, and rise more forcibly in the longer tube, in proportion to its degree of heat or rarefaction, and length of that tube. For such a machine is a kind of inverted siphon; and, as the greater weight of water in the longer leg of a common siphon in descending is accompanied by an ascent of the same fluid, in the shorter; so, in this inverted siphon, the greater quantity of levity of air in the longer leg, in rising is accompanied by the descent of air in the shorter. The things to be burned being laid on the hot coals at A, the smoke must descend through those coals, and be converted into flame, which, after destroying the offensive smell, came out at the end of the longer tube as mere heated air.

"Whoever would repeat this experiment with success, must take care that the part A B, of the short tube, be quite full of burning coals, so that no part of the smoke may descend and pass by them without going through them, and being converted into flame; and that the longer tube be so heated as that the current of ascending hot air is esablished in it before the things to be burnt are laid on the coals; otherwise there will be a disappointment."

* * * * * * *

"The stove I am about to describe was also formed on the idea given by the French experiment, and completely carried into execution before I had any knowledge of the German invention; which I wonder should remain so many years in a country, where men are so ingenious in the management of fire, without receiving long since the improvements I have given it.

Description of the Parts.

"A, the bottom plate which lies flat upon the hearth, with its partitions, 1, 2, 3, 4, 5, 6, (Plate, our fig. 17, No. 2) to slide the bottom edges of the small plates Y, Y, No. 12; which plates meeting at X, close the front.

"B 1, No. 3, is the cover plate showing its under side, with the grooves 1, 2, 3, 4, 5, 6, to receive the top edges of the partitions that are fixed to the bottom plate. It shows also the grate W W, the bars of which are cast in the plate, and a groove V V, which comes right over the groove Z Z, No. 2, receiving the upper edges of the small sliding plates Y Y, No. 12.

"B 2, No. 4, shows the upper side of the same plate with a square impression or groove for receiving the bottom mouldings T T T T of the three-sided box C, No. 5, which is cast in one piece.

"D, No. 6, its cover, showing its under side with grooves to receive the upper edges S S S of the sides of C, No. 5, also a groove R R, which, when the cover is put on, comes right over another, Q Q in C, No. 5, between which is to slide.

"E, No. 7, the front plate of the box.

"P, a hole three inches diameter through the cover D, No. 6, over which hole stands the vase F, No. 8, which has a corresponding hole two inches diameter, through its bottom.

"The top of the vase opens at O O O, No. 8, and turns back upon a hinge behind, when coals are to be put in; the vase has a grate within at N N of cast iron H, No. 9, and a hole in the top one and a half inches in diameter, to admit air, and to receive the ornamental brass gilt flame M, No. 10, which stands in that hole, and being itself hollow and open, suffers air to pass through it to the fire.

"G, No. 11, is a drawer of plate iron, that slips in between the partitions 2 and 3, No. 2, to receive the falling ashes. It is concealed when the small sliding plates Y, Y, No. 12, are shut together.

"I I I I, No. 8, is a niche built of brick in the chimney, and plastered. It closes the chimney over the vase, but leaves two funnels, one in each corner, communicating with the bottom box K K, No. 2."

As we have repeatedly seen, Franklin was essentially a utilitarian. Wherever possible, he set himself the task of directly applying the principles of any great natural law he had discovered to some useful purpose. We see this in his great invention of the lightning rod. It is also to be observed in his invention of the Pennsylvania Fire-place, as well as the stove with the downward draught, that was capable of burning in a closed room, not only pit coal, but even substances that would, in an ordinary stove, give out either exceedingly disagreeable or noxious odors, or both.

To the same type of investigation is Franklin's study of the Gulf Stream. No sooner does he hear of the existence of this stream of heated water, flowing as it does along the eastern coast of the United States, in the direct path of vessels sailing between America and Europe, than he sets himself the task of having a chart drawn of this body of water, which he has engraved, sending copies to such parts of the world as would be most likely to be of benefit, thus enabling a navigator to turn what had been an evil, so far as it retarded the speed of his vessel when sailing in certain directions, into an advantage when sailing in opposite directions. Again, while this practical philosopher is employing the thermometer in determining the limits of the Gulf Stream, he points out how such use may possibly be of value to other navigators in teaching them how to avoid cold currents in the Northern Hemisphere, which, as is well known, generally tend to move from the north towards the south.

It was in this line of applied physics that Franklin made the study of the effects produced on the comfort of the individual ensured by wearing woolen clothes in cold wintry weather, and linen clothes in hot summer weather. In a letter to John Lining, of Charlestown, South Carolina, dated New York, April 14, 1757, he treats of a variety of topics, mainly, however, relating to the cold produced by evaporation. It is in this letter that he thus speaks of the effect produced by clothing:

"Thus, as by a constant supply of fuel in a chimney, you keep a room warm, so, by a constant supply of food in the stomach, you keep a warm body; only where little exercise is used, the heat may possibly be conducted away too fast; in which case such materials are to be used for clothing and bedding, against the effects of an immediate contact of the air, as are, in themselves, bad conductors of heat, and, consequently, prevent its being communicated thro' their substance to the air. Hence what is called warmth in wool, and its preference, on that account, to linnen; wool not being so good a conductor: And hence all the natural coverings of animals, to keep them warm are such as to retain and confine the natural heat in the body, by being bad conductors, such as wool, hair, feathers, and the silk by which the silk worm, in its tender embrio state, is first cloathed. Cloathing thus considered does not make a man warm by giving warmth, but by preventing the too quick dissipation of the heat produced in his body, and so occasioning an accumulation."

Franklin here gives the true explanation of the source of animal heat as the food consumed by the animal. He points out the fact that clothing does not itself supply heat to the body, but merely prevents the too rapid loss of the heat produced by the animal's food. By employing as clothing such poor conductors as wool or fur, the heat of the body is prevented from being rapidly passed into the surrounding air. Wool may properly be called warm because it is a poor conductor of heat, but not because it possesses any heat in itself. Linen, on the contrary, produces a cooling effect in that it permits the heat of the body to be rapidly passed or conducted through it to the surrounding air.

Franklin gave considerable thought to the effect of external heat on the temperature of the bodies of healthy animals. He notices the fact that it is possible for a healthy living animal to be exposed to a very high temperature without any notable increase in its temperature. In another letter to John Lining, of Charlestown, dated London, June 17, 1758, he gives an ac-

count of an exceedingly hot Sunday that occurred in Philadelphia in June, 1750, with the thermometer at 100° in the shade:

"May not several phenomena hitherto unconsidered, or unaccounted for be explained by this property? (a) During the hot Sunday at Philadelphia, in June, 1750, when the thermometer was up at 100 in the shade, I sat in my chamber without exercise, only reading or writing, with no other cloathes on than a shirt, and a pair of long linen drawers, the windows all open, and a brisk wind blowing through the house, the sweat ran off the backs of my hands, and my shirt was often so wet, as to induce me to call for dry ones to put on; in this situation, one might have expected, that the natural heat of the body 96, added to the heat of the air 100, should jointly have created or produced a much greater degree of heat in the body; but the fact was, that my body never grew so hot as the air that surrounded it, or the immediate bodies immers'd in the same air. For I remember well that the desk, when I laid my arm upon it; a chair, when I sat down in it; and a dry shirt out of the drawer, when I put it on, all felt exceeding warm to me, as if they had been warmed before a fire. And I suppose a dead body would have acquired the temperature of the air, though a living one, by continual sweating, and by the evaporation of that sweat, was kept cold.

"(b) May not this be a reason why our reapers in Pennsylvania, working in the open field in the clear, hot sunshine common in our harvest time, find themselves well able to go through that labor, without being much incommoded by the heat, while they continue to sweat, and while they supply matter for keeping up that sweat, by drinking frequently of a thin, evaporable liquor, water mixed with rum; but, if the sweat stops, they drop, and sometimes die suddenly, if a sweating is not again brought on by drinking that liquor, or, as some rather choose in that case, a kind of hot punch, made with water, mixed with honey, and a considerable proportion of vinegar? May there not be in negroes a quicker evaporation of the perspirable matter from their skins and lungs, which, by cooling them more, enables them to bear the sun's heat better than whites do? (if that is a fact, as it is said to be; for the alleged necessity of having negroes, rather than whites, to work in the West India fields, is founded upon it,) though the color of their skins would otherwise make them more sensible of the sun's heat, since black cloth heats much sooner and more, in the sun, than white cloth. I am persuaded, from several instances happening within my knowledge, that they do not bear cold weather so well as the whites; they will perish when exposed to a less degree of it, and are more apt to have their limbs frost-bitten; and may not this be from the same cause?"

(a) Franklin notes correctly the fact that, although the thermometer was 100° in the shade, and his clothing was of such a nature as to readily expose the body to the external air, nevertheless the temperature of his body did not greatly ex-

ceed its natural temperature, never, in fact, growing as hot as the surrounding air; for, as he remarks, his body was evidently colder than the desk on which he laid his arm, was colder than the chair he sat on, or the dry shirt that he took out of the drawer to replace the wet one he had on. His reference to the effect that a high temperature would produce on a dead body is also in accordance with well known facts. It is possible for a man to go into an oven, the temperature of which is sufficiently high to bake a trussed fowl, which he carries in with him, and to safely remain in such an oven until the fowl is thoroughly cooked, and then to come out unharmed. Franklin's explanation is correct as to the cause; viz., that the living body protects itself by permitting the heat to evaporate the moisture it is constantly throwing out to the surface, and thus prevent it from entering the body.

(b) The explanation concerning the Pennsylvania reapers is also correct. Their safety, while under exposure to the hot sun, is ensured by drinking copious draughts of water, the rum being very likely a matter of taste, rather than of necessity.

In another letter, dated September 20th, 1761, to a Miss Mary Stevenson, Franklin refers to the effect produced by the sun's rays on clothes of different colors as follows:

"(a) As to our other subject, the different degrees of heat imbibed from the sun's rays by cloths of different colours, since I cannot find the notes of my experiment to send you, I must give it as well as I can from memory.

(b) "But first let me mention an experiment that you can easily make yourself. Walk but a quarter of an hour in your garden when the sun shines, with a part of your dress white, and a part black; then apply your hand to them alternately, and you will find a very great difference in warmth. The black will be quite hot to the touch, the white still cool.

(c) Another. Try to fire paper with a burning-glass. If it is white, you will not easily burn it; but if you bring the focus to a black spot, or upon letters, written or printed, the paper will immediately be on fire under the letters.

"Thus fullers and dyers find black cloths, of equal thickness with white ones, and hung out equally wet, dry in the sun much sooner than the white, being more readily heated by the sun's rays. It is the same before a fire; the heat of which sooner penetrates black stockings than white ones, and so is apt sooner to burn a man's shins. Also beer much sooner warms in a black mug set before the fire, than in a white one, or in a bright silver tankard.

(d) "My experiment was this. I took a number of little square pieces of broad cloth from a taylor's pattern card, of various colours. There were black, deep blue, lighter blue, green, purple, red, yellow, white, and all other colours, or shades of colours. I laid them all upon the snow in a bright, sun-shiny morning. In a few hours (I cannot now be exact as to the time) the black being warmed most by the sun was sunk so low as to be below the stroke of the sun's rays; the dark blue almost as low, the lighter blue not quite so much as the dark, the other colours less as they were lighter; and the quite white remained on the surface of the snow, not having entered it at all.

(e) "What signifies philosophy that does not apply to some use? May we not learn from hence, that black clothes are not so fit to wear in a hot sunny climate or season, as white ones; because in such clothes the body is more heated by the sun when we walk abroad, and are at the same time heated by the exercise, which double heat is apt to bring on putrid dangerous fevers? That soldiers and seamen who must march and labour in the sun, should in the East or West Indies have a uniform of white? That summer hats for men or women should be white, as repelling that heat which gives headaches to many, and to some the fatal stroke that the French call the Coup de Soleil? That the ladies Summer hats, however, should be lined with black, as not reverberating on their faces those rays which are reflected upwards from the earth or water? That the putting of a white cap of paper or linen within the crown of a black hat, as some do, will not keep out the heat, tho' it would if plac'd without. That fruit walls being blacked may receive so much heat from the sun in the daytime, as to continue warm in some degree thro' the night, and thereby preserve the fruit from frosts, or forward its growth? With sundry other particulars of less or greater importance, that will occur from time to time to inattentive minds?"

(a) It will be noticed that this investigation is not unlike a prior investigation in which Franklin pointed out the effects produced on the temperature of the human body, arising from the use of textile fabrics that varied in their power of conducting or transferring heat. Here, however, the investigation refers only to the influence of the color of fabrics on their ability to take in heat from an external source, such as the sun.

(b) A simple but crucial experiment. After an exposure of say a quarter of an hour to the hot sun, the fact that different portions of the clothing will have been differently heated according to their color, can be readily determined by simply touching the different articles of dress, when the darker colored ones will be found to be much warmer than the light colored ones.

(c) This employment of a burning glass or convex lens is

very simple, but quite convincing. Black paper can be easily fired or burned by the concentrated solar focus of the burning glass, while white paper cannot.

(d) A charming experiment, just of the character that we should expect this true philosopher to make. With no other means than simple squares of different colored cloths of the same size for the materials which are to be exposed to the sun's heat, and with no other thermometric apparatus than the ground covered with a layer of snow, an excellent test is made. Franklin places the squares of cloth on the snow, and exposes them for a few hours to the radiation of the sun. The fact that different temperatures have been attained by the cloths varying with their color, is evident by some of them having sunk a considerable distance into the snow, while others remain apparently unaffected. It is needless to add that, in this case, it was the black cloths that sank the farthest, the dark blue

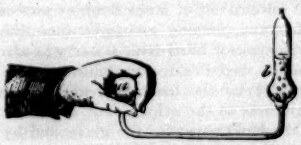


Fig. 18. Franklin's Pulse Glass.

cloths the next farthest, and then the light blue, while the pure white cloths scarcely showed any effect whatever.

(e) Here, again, the utilitarian side of the philosopher asserts itself. The application of these facts is evident. Black clothes are unsuited to wear in a hot climate; white ones should be employed.

Of a somewhat similar character, though undertaken some time before the experiments we have just referred to, are Franklin's experiments with a form of apparatus that is now known in the physical laboratory as the pulse glass. Such a device is represented in Fig. 18. This consists of two vertical glass bulbs, a and b, connected by means of a horizontal tube of small diameter. The apparatus is partially filled with water, though, in more modern forms, preferably with ether, which has a much lower boiling point. While the upper end of the glass tube, b, is

still open, the water in the bulb is vigorously boiled, so as to expel the air, when the tube is hermetically sealed by the fusion of the glass. By reason of the vacuum thus produced in the tube, the temperature of the boiling point of the liquid is considerably lowered, so that the heat of the hand placed at a, as shown in the figure, is sufficient to cause a brisk boiling of the liquid.

It would appear from a letter written by Franklin to John Winthrop, dated London, July 2, 1768, that Franklin obtained a tube of this character in Germany, during the preceding year. Franklin refers to this matter as follows:

"I have nothing new in the philosophical way to communicate to you, except what follows. When I was last year in Germany I met with a singular kind of glass, being a tube about eight inches long, half an inch in diameter, with a hollow ball of near an inch diameter at one end, and one of an inch and a half at the other, hermetically sealed, and half filed with water. If one end is held in the hand, and the other a little elevated above the level, a constant succession of large bubbles proceeds from the end in the hand to the other end, making an appearance that puzzled me much, till I found that the space not filled with water was also free from air, and either filled with a subtle, invisible vapor, continually rising from the water, and extremely rarefiable by the least heat at one end, and condensable again by the least coolness at the other; or it is the very fluid of fire itself, which parting from the hand pervades the glass, and by its expansive force depresses the water till it can pass between the glass and escapes to the other end, where it gets through the glass again into the air. I am rather inclined to the first opinion, but doubtful between the two.

"An ingenious artist here, Mr. Nairne, mathematical instrument maker, has made a number of them from mine, and improved them; for his are much more sensible than those I brought from Germany. I bored a very small hole through the wainscot in the seat of my window, through which a little cold air constantly entered, while the air in the room was kept warmer by fires made daily in it, being winter time. I placed one of his glasses, with the elevated end against this hole: and the bubbles from the other end, which was in a warmer situation, were continually passing day and night, to the no small surprise of even philosophical spectators. Each bubble discharged is larger than that from which it proceeds, and yet that is not diminished; and by adding itself to the bubble at the other end, that bubble is not increased, which seems very paradoxical.

"When the balls at each end are made large and the connecting tube very small, and bent at right angles, so that the balls, instead of being at the ends, are brought on the side of the tube, and the tube is held so that the balls are above it, the water will be depressed in that which is held in the hand, and rise in the other as a jet or fountain; when it is all in the other, it begins to boil, as it were, by the vapor passing up through it; and the

instant it begins to boil, a sudden coldness is felt in the ball held; a curious experiment this, first observed and shown me by Mr. Nairne. There is something in it similar to the old observation, I think, mentioned by Aristotle, that the bottom of a boiling pot is not warm; and perhaps it may help to explain that fact, if indeed it be a fact.

"When the water stands at an equal height in both these balls, and all at rest, if you wet one of the balls by means of a feather dipped in spirit, though that spirit is of the same temperament as to heat and cold with the water in the glasses, yet the cold occasioned by the evaporaion of the spirit from the wetted ball, will so condense the vapor over the water contained in that ball, as that the water of the other ball will be pressed up into it, followed by a succession of bubbles, till the spirit is all dried away. Perhaps the observations on these little instruments may suggest and be applied to some beneficial uses. It has been thought, that water reduced to vapor by heat was rarefied only fourteen thousand times, and on this principle our engines for raising water for fire are said to be constructed; but, if the vapor so much rarefied from water is capable of being itself still further rarefied to a boundless degree, by the application of heat to the vessels or parts of vessels containing the vapor (as at first it is applied to those containing the water), perhaps a much greater power may be obtained, with little additional expense. Possibly, too, the power of easily moving water from one end to the other of a moveable beam (suspended in the middle like a scale-beam) by a small degree of heat, may be applied advantageously to some other mechanical purposes."

Franklin's explanation of the phenomena of the pulse glass was, generally speaking, correct. His manner of increasing the difference of temperature between the two bulbs was ingenious, though simple; *i. e.*, by subjecting these two bulbs to the temperature of the outer air, and of a heated room, respectively, by placing one bulb near a small hole bored through the wainscot in a window seat, through which a small quantity of cold air entered, and leaving the other bulb exposed to the warm air of the room.

During the latter part of his life, Franklin suffered from failing sight. When seventy-nine years of age, he refers to this matter, in a letter to George Whatley, dated Passy, August 21, 1784, as follows:

"Your eyes must continue very good since you can write so small a hand without spectales. I cannot distinguish a letter even of large print; but am happy in the invention of double spectacles, which, serving for distant objects as well as near ones, make my eyes as useful to me as ever they were. If all the other defects and infirmities were as easily and cheaply remedied, it would be worth while for friends to live a great deal

longer, but I look upon death to be as necessary to our constitution as sleep. We shall rise refreshed in the morning."

The double spectacles to which he refers as having invented are what are now generally called bifocals. They were made for Franklin under his direction, in Paris, by a French optician. Franklin thus describes these spectacles in a letter to George Whatley, dated Passy, May 23, 1785:

"By Mr. Dollond's saying that my double spectacles can only serve particular eyes, I doubt he has not been rightly informed of their construction. I imagine it will be found pretty generally true, that the same convexity of glass, through which a man sees clearest and best at the distance proper for reading, is not the best for greater distances. I therefore had formerly two pairs of spectacles, which I shifted occasionally, as in travelling I sometimes read, and often wanted to regard the prospects. Finding this change troublesome, and not always sufficiently ready, I had the glasses cut, and half of each kind associated in the same circle, thus—

Fig. 19. Franklin's Double Spectacles or Bifocals.

By this means, as I wear my spectacles constantly, I have only to move my eyes up or down, as I want to see distinctly far or near, the proper glasses being always ready. This I find more particularly convenient since my being in France; the glasses that serve me best at the table to see what I eat, not being the best to see the faces of those on the other side of the table who speak to me; and when one's ears are not well accustomed to the sound of a language, a sight of the movements in the features of him that speaks, helps to explain; (a) so that I understand French better by the help of my spectacles."

(a) By this witty remark, Franklin of course refers to the fact that he made up, by the use of his eyes, for what his ears lacked in thoroughly appreciating the sounds of a language to which he was not accustomed.

While in London, on one of his many visits to England, Franklin saw a musical instrument called an armonica. This instrument consists of glass vessels of varying sizes, which when rubbed by passing the moistened finger around their rims, emits the notes of the musical scale or gamut. Being much pleased with the sweetness of its notes, Franklin greatly

improved the instrument, so as to increase the number of tones it was capable of producing, while, at the same time, placing it in a much smaller space.

In Franklin's improved form of armonica, the different glasses were made in the form of hemispheres, provided with an open neck and a socket in the middle for fixing them to an iron spindle. The spindle, holding the glasses, was placed horizontally and moved by a treadle in a manner similar to that of the spinning wheel. The performer sat in front of the instrument and brought out the required tones by placing the moistened fingers on the rims of the rotating glass.

Franklin describes his improved instrument in a letter written to the Rev. John Baptist Becearia, dated London, July 13, 1762:

"I once promised myself the pleasure of seeing you at Turin; but as that is not now likely to happen, being just about returning to my native country, America, I sit down to take leave of you (among other of my European friends that I cannot see) by writing.

"I thank you for the honorable mention you have so frequently made of me in your letters to Mr. Collinson and others, for the generous defence you undertook and executed with so much success, of my electrical opinions; and for the valuable present you have made me of your new work, from which I have received great information and pleasure. I wish I could in return entertain you with anything new of mine on that subject; but I have not lately pursued it. Nor do I know of any one here, that is at present much engaged in it.

"Perhaps, however, it may be agreeable to you, as you live in a musical country, to have an account of the new instrument lately added here to the great number that charming science was before possessed of. As it is an instrument that seems peculiarly adapted to Italian music, especially that of the soft and plaintive kind, I will endeavour to give you a description of it, and of the manner of constructing it, that you or any of your friends may be able to imitate it, if you incline to do so, without being at the expense add trouble of the many experiments I have made in endeavouring to bring it to its present perfection.

"You have doubtless heard the sweet tone that is drawn from a drinking-glass by passing a wet finger around its brim. One Mr. Puckeridge, a gentleman from Ireland, was the first who thought of playing tunes, formed of these tones. He collected a number of glasses of different sizes, fixed them near each other on a table, and tuned them by putting into them water more or less, as each note required. The tones were brought out by passing his fingers round their brims. He was unfortunately burned here, with his instrument, in a fire which consumed the house he lived in. Mr. E. Delaval, a most ingenious member of our Royal Society,

made one in imitation of it, with a better choice and form of glasses, which was the first I saw or heard. Being charmed by the sweetness of its tones, and the music he produced from it, I wished only to see the glasses disposed in a more convenient form, and brought together in a narrower compass, so as to admit of a greater number of tones, and all within reach of hand to a person sitting in front of the instrument, which I accomplished, after various intermediate trials and less commodious forms, both of glasses and construction in the following manner:

"The glasses are blown as near as possible in the form of hemispheres, having each an open neck or socket in the middle. (Fig. 20.) The thickness of the glass near the brim about a tenth of an inch, or hardly quite so much, but thicker as it comes nearer the neck, which in the largest glasses is about an inch deep, and an inch and a half wide within, these dimensions lessening, as the glasses themselves diminish in size, except that the neck of the smallest ought not to be shorter than half an inch. The largest glass is nine inches diameter, and the smallest three inches. Between these two are twenty-three different sizes, differing from each other a quarter of an inch in diameter. To make a single

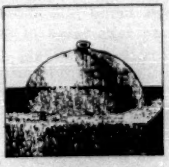


Fig. 20

instrument there should be at least six glasses blown of each size; and out of this number one may probably pick thirty-seven glasses (which are sufficient for three octaves with all the semi-tones) that will be each either the note one wants or a little sharper than that note, and all fitting so well into each other as to taper pretty regularly from the largest to the smallest. It is true that there are not thirty-seven sizes, but it often happens that two of the same size differ a note or half note in tone, by reason of a difference in thickness, and these may be placed one in the other without sensibly hurting the regularity of the taper form.

"The glasses being chosen and every one marked with a diamond the note you intend for it, they are to be tuned by diminishing the thickness of those that are too sharp. This is done by grinding them round from the neck towards the brim, the breadth of one or two inches, as may be required; often trying the glass by a well-tuned harpischord, comparing the tone drawn from the glass by your finger, with the note you want, as sounded by that string of the harpischord. When you come nearer the matter, be careful to wipe the glass clean and dry before each trial, because the tone is somewhat flatter when the glass is wet, than it will be when dry; and, grinding a very little between each trial, you will thereby tune to great exactness. The more care is necessary in this, be-

cause, if you go below your required tone, there is no sharpening it again but by grinding somewhat off the brim, which will afterwards require polishing, and thus increase the trouble.

"The glasses being thus tuned, you are to be provided with a case for them, and a spindle on which they are to be fixed. (Fig. 21.) My case is about three feet long, eleven inches every way wide within at the biggest end, and five inches at the smallest end; for it tapers all the way, to adapt it better to the conical figure of the set of glasses. This case opens in the middle of its height, and the upper

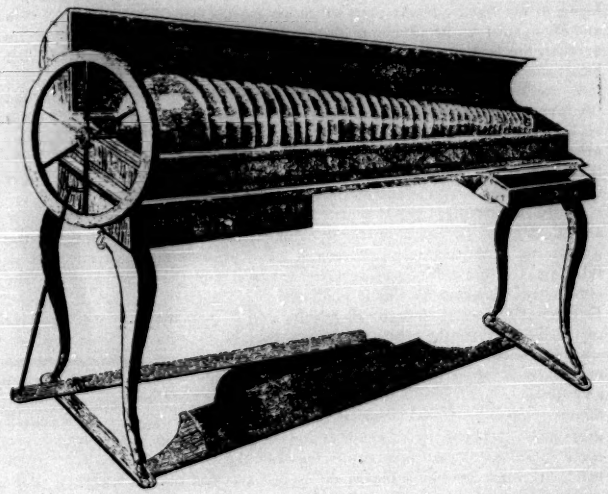


Fig. 21.

part turns up by hinges fixed behind. The spindle, which is of hard iron, lies horizontally from end to end of the box within, exactly in the middle, and is made to turn on brass gudgeons at each end. It is round, an inch diameter at the thickest end, and tapering to a quarter of an inch at the smallest. A square shank comes from its thickest end through the box, on which shank a wheel is fixed by a screw. This wheel serves as a fly to make the motion equable, when the spindle, with the glasses, is turned by the foot like a spinning wheel. My wheel is of mahogany, eighteen inches diameter, and pretty thick, so as to conceal near its circumference about twenty-five pounds of lead. An ivory pin is fixed on the face of this wheel, and about four inches from the axis. Over the neck of this pin is put the loop of the string that comes up from the movable step to give it motion. The case stands on a neat frame with four legs.

"To fix the glasses on the spindle, a cork is first to be fitted in each neck pretty tight, and projecting a little without the neck, that the neck of one may not touch the inside of another when put together, for that would make a jarring. These corks are to be perforated with holes of different diameters, so as to suit that part of the spindle on which they are to be fixed. When a glass is put on, by holding it stiffly between both hands, while another turns the spindle, it may be gradually brought to its place. But care must be taken that the hole is not too small, lest, in forcing it up, the neck should be split; nor too large, lest the glass, not being firmly fixed, should turn or move on the spindle, so as to touch and jar against its neighboring glass. The glasses are thus placed one in another, the largest on the biggest end of the spindle, which is to the left hand; the neck of this glass is towards the wheel, and the next goes into it in the same position, only about an inch of its brim appearing beyond the brim of the first; thus proceeding, every glass when fixed, shows about an inch of its brim (or three-quarters of an inch, or half an inch, as they grow smaller) beyond the brim of the glass that contains it; and it is from these exposed parts of each glass that the tone is drawn, by laying a finger upon one of them as the spindle and glasses turn round.

"My largest glass is G, a little below the reach of a common voice, and my highest G, including three complete octaves. To distinguish the glasses the more readily to the eye, I have painted the apparent part of the glasses within side, every semi-tone, white, and the other notes of the octave with the seven prismatic colors, viz: C, red; D, orange; E, yellow; F, green; G, blue; A, indigo; B, purple; and C, red again; so that glasses of the same color (the white excepted) are always octaves to each other.

"This instrument is played upon by sitting before the middle of the set of glasses as before the keys of a harpischord, turning them with the foot and wetting them now and then with a sponge and clean water. The fingers should be first a little soaked in water, and quite free from all greasiness; a little fine chalk upon them is sometimes useful, to make them catch the glass and bring out the tone more readily. Both hands are used, by which means different parts are played together. Observe, that the tones are best drawn out when the glasses turn from the ends of the fingers, and not when they turn to them.

"The advantages of this instrument are, that its tones are incomparably sweet, beyond those of any other; that they may be swelled and softened at pleasure by stronger or weaker pressure of the finger, and continued to any length; and that the instrument, being once well tuned, never again wants tuning.

"In honor of your musical language, I have borrowed from it the name of this instrument, calling it the Armonica.

"With great esteem and respect, I am, &c., B. Franklin."

Franklin gives the following directions as to the best manner of obtaining the sweet notes this instrument is capable of producing:

"Before you sit down to play, the fingers should be well washed with soap and water, and the soap well rinsed off.

"The glasses must always be kept perfectly clean from the least greasiness; therefore suffer nobody to touch them with unwashed hands, for even the common, slight, natural greasiness of the skin rubbed on them will prevent their sounding for a long time.

"You must be provided with a little bottle of rain water, (spring water is generally too hard, and produces a harsh tone,) and a middling sponge

Fig. 22. Franklin's Improvement on the Armonica.

in a little slop-bowl, in which you must keep so much of the water that the sponge may always be very wet.

"In a teacup keep also ready some fine scraped chalk, free from grit, to be used on occasion.

"The fingers when you begin to play should not only be wet on the surface, but the skin a little soaked, which is readily done by pressing them hard a few times in the sponge.

"The first thing after setting the glasses in motion is to pass the sponge slowly along from the biggest glass to the smallest, suffering it to rest on

each glass during at least one revolution of the glasses, whereby they will all be made moderately wet. If too much water is left on them, they will not sound so readily.

"If the instrument is left near a window, let the window be shut or the curtain drawn, as wind or sunshine on the glasses dries them too fast.

"When these particulars are all attended to, and the directions observed, the tone comes forth finely with the slightest pressure of the fingers imaginable, and you swell it at pleasure by adding a little more pressure, no instrument affording more shades, if one may so speak, of the Forte piano.

"One wetting with the sponge will serve for a piece of music twice as long as Handel's Water-piece, unless the air be uncommonly drying.

"But a number of thin slices of sponge, placed side by side, their ends held fast between two strips of wood, like rulers, of a length equal to the glasses, and placed so that the loose ends of the sponges may touch the glasses behind, and by that means keep them constantly wet, is very convenient where one purposes to play for a long time. The sponges being properly wetted will supply the glasses sufficiently a whole evening, and touching the glasses lightly do not in the least hurt the sound.

"The powder of chalk is useful two ways.

"Fingers, after much playing, sometimes begin to draw out a tone less smooth and soft, and you feel as well as hear a small degree of sharpness. In this case, if you dip the ends of your wet fingers in the chalk, it will immediately recover the smoothness of tone desired. And, if the glasses have been sullied by handling, or the fingers not being just washed have some little greasiness on them, chalk so used will clean both glasses and fingers, and the sounds will come out to your wish.

"A little practice will make all this familiar; and you will also find by trials what part of the fingers most readily produces the sound from particular glasses, and whether they require to be touched on the edge chiefly, or a little more on the side; as different glasses require a different touch, some pretty full on the flat side of the brim, to bring out the best tone, others more on the edge, and some of the largest may need the touch of two fingers at once."

Fig. 22 represents a photograph of an armonica, constructed by Franklin. As will be seen, it differs in no respect from the one represented in Figs, 20 and 21, save in some unimportant details. The position of the musician operating this instrument, however, is clearly shown in the photograph.*

Pitt Rivers Museum, University of Oxford, Sep. 9, 1904.

DEAR DR. GOLDSCMIDT:

Thank you very much for having so kindly sent me the photograph

*As will be seen from the accompanying letter, dated Sep. 27, 1904, from Prof. Henry Balfour, of the University of Oxford, transmitted by Dr. V. Goldsmidt, the construction is the same as that already given above.

which is *very* interesting to me. The instrument represented is not a stringed instrument but a "Glasharmonica" and consists of 20 or more hemispherical glass bowls all fixed upon a long rod or spindle, which passes through the centres. One end of the spindles is attached to a wheel, which can be rotated by means of a pedal or foot board. When the wheel is set revolving (by pedalling with the foot) all the glasses revolve together and as they are carefully graduated in size (the base on the cleft and treble on the right) scales can be played or even chords and harmonics. The performer wets his fingers and rests them upon the revolving glasses; the friction causing them to vibrate and emit their respective notes. Your picture illustrates the method of playing excellently. I enclose a rough sketch of the instrument from the base end to show the wheel and treadle and also one to show how the bowls are fixed onto the spindle, overlapping so as to bring them all as close together as possible to allow of harmonics and chords being played. This form of the instrument was invented by the celebrated American, *Benjamin Franklin*, about the year 1760, and was an improvement upon the earlier musical glasses upon which the celebrated composer Glueck used to perform.

I have seen very few examples of the "Glasharmonica." There is one in the South Kensington Museum in London and I have seen two or three other examples. You are fortunate to have this picture, which from the costume would seem to date from 1780-1800. Can you tell me, if it is dated exactly and whom it represents in the act of playing? I assume that the picture is German.

Thanking you again for the photograph and with kindest regards.

Yours very truly,

HENRY BALFOUR.

Franklin correctly ascribes the phenomena of St. Elmo's fire, or as they are generally called by sailors, corposants or comazants, to electrical point discharges. He thus refers to these phenomena in a letter to Collinson, dated July 27, 1750:

"June 29, 1751. In Capt. Waddell's account of the effects of lightning on his ship, I could not but take notice of the large comazants (as he calls them) that settled on the spintles at the top-mast heads, and burnt like very large torches (before the stroke). According to my opinion, the electrical fire was then drawing off, as by points, from the cloud: the largeness of the flame betokening the great quantity of electricity in the cloud: and had there been a good wire communication from the spindle heads to the sea, that could have conducted more freely than tarred ropes, or masts of turpentine wood, I imagine there would either have been no stroke; or, if a stroke, the wire would have conducted it all into the sea without damage to the ship."

It will be remembered that while discussing the Franklin letter, in which he describes the construction of his movable elec-

tric clouds; *i. e.*, the cloud consisting of a movable pasteboard tube or of a charged scale pan of a balance, reference was made to the fact that Franklin had conceived an erroneous idea concerning what he called cold fusion, the reference to which was deferred to another part of the article. This we were also the more willing to do, from the fact that this article contained reference to important matters of a different character.

It would appear that Franklin was led to this change of opinion concerning the cold fusion of metals as follows: His friend Kinnersley, of London, had sent to Franklin a letter describing a form of electrical thermometer he had devised. This

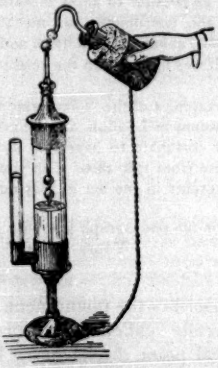


Fig. 47. Paged 17, Vol. 1. Electricity in Every-day Life. Our Fig. 23.

form of thermometer consisted as represented in Fig. 23, of two glass stubs of unequal diameter, communicating with each other at their lower ends by means of a horizontal tube. A metallic cap closes the upper end of the larger tube. Through this cap a metallic rod extends, terminating at both of its ends in smooth metallic balls, the opening being of such dimension that the rod can be slid up and down with some little friction. Another metallic ball is attached to the upper end of a metallic rod, permanently fixed in the lower part of the enclosed tube as shown. The sliding rod is so placed as to leave a small air gap between it and the lower end of the ball

connected with the fixed rod. As will be seen, the smaller tube is left open at the top. Sufficient water is placed in the tube to bring the level of the liquid below the top of the lower fixed ball. When, now, a disruptive discharge is passed between the two balls in the enclosed tube, by the discharge of a Leyden jar, the heat produced causes an expansion of the contained air, and so depresses the column of water in the enclosed tube, rising the level in the open tube. With powerful discharges, the water may even be violently thrown out from the top of the smaller tube, a part of this movement being due to the sudden blow or motion given to the air by the discharge. That, however, the depression of the column is also due to the increase in the temperature of the air consequent on the passage of the discharge, is seen by the fact that the water is maintained at a higher level in the open tube until the air in the enclosed tube has reached its former temperature.

In the same letter, Kinnersley describes another experiment which he made in accordance with a suggestion of Franklin, that also refers to what Franklin calls cold fusion. Kinnersley's description of this experiment is as follows:

"I then suspended, out of the thermometer, a piece of small harpischord wire, about twenty-four inches long, with a pound weight at the lower end, and sent the charge of the case of five and thirty bottles through it, whereby, (a) I discovered a new method of wire-drawing. The wire was red-hot the whole length, well annealed, and above an inch longer than before. A second charge melted it; it parted near the middle, and measured, when the ends were put together, four inches longer than at first. This experiment, I remember, you proposed to me before you left Philadelphia; but I never tried it till now. That I might have no doubt of the wire's being *hot* as well as red, I repeated the experiment on another piece of the same wire, encompassed with a goose-quill, filled with loose grains of gunpowder; which took fire as readily as if it had been touched with a red-hot poker. Also tinder, tied to another piece of the wire, kindled by it. I tried a wire about three times as big, but could produce no such effects as that.

"Hence it appears that the electric fire, though it has no sensible heat when in a state of rest, will, by its violent motion, and the resistance it meets with, produce heat in other bodies when passing through them, provided they be small enough. A large quantity will pass through a large wire without producing any sensible heat; when the same quantity, passing through a very small one, being more confined to a narrower passage, the particles crowding closer together and meeting with greater resistance, will make it red-hot, and even melt it.

"Hence lightning does not melt metal by a cold fusion, as we formerly supposed; but when it passes through the blade of a sword, if the quantity be not very great, it may heat the point so as to melt it, while the broadest and thickest part may not be sensibly warmer than before.

"And, when trees or houses are set on fire by the dreadful quantity which a cloud, or the earth, sometimes discharges, must not the heat by which the wood is first kindled, be generated by the lightning's violent motion through the resisting combustible matter?"

(a) "I discovered a new method of wire-drawing." Here we have a good description of a method for electrically drawing and annealing wire, made at a time when the voltaic heated the steel wire to such an extent as to permit it to be drawn out, and, on the passage of a second discharge, to be drawn out still further (at this time the wire breaking), the elongation produced by the two discharges measuring about four inches. At the same time, the wire was annealed by reason of the gradual cooling to which it was exposed. This experiment was, as Kinnersley acknowledged, suggested by Franklin.

Franklin's reply to this letter of Kinnersley was dated London, February 20th, 1762, and was as follows:

(a) "I am much pleased with your electrical thermometer, and the experiments you have made with it. I formerly satisfied myself, by an experiment with my phial and siphon, that the elasticity of the air was not increased by the mere existence of an electric atmosphere within the phial; but I did not know, till you now inform me, that heat may be given to it by an electric explosion. The continuance of its rarefaction, for some time after the discharge of your glass jar and your case of bottles, seems to make this clear. The other experiments on wet paper, wet thread, green grass, and green wood, are not so satisfactory; as possibly the reducing part of the moisture to vapor, by the electric fluid passing through it, might occasion some expansion which would be gradually reduced by the condensation of such vapor. The fine silver thread, the very small brass wire, and the strip of gilt paper, are also subject to a similar objection, as even metals, in such circumstances, are often partly reduced to smoke, particularly the gilding on paper.

(b) "But your subsequent beautiful experiment on the wire, which you made hot by the electric explosion, and in that state fired gunpowder with it, puts it out of all question, that heat is produced by our artificial electricity, and that the melting of metals in that way, is not what I formerly called a cold fusion. A late instance here of the melting of the bell-wire, in a house struck by lightning, and parts of the wire burning holes in the floor on which they fell, has proved the same with regard to the electricity of nature. I was too easily led into that error by accounts given

even in philosophical books, and from remote ages downwards, of melting money in purses, swords in scabbards, &c., without burning the inflammable matters that were so near those melted metals. But men are, in general, such careless observers, that a philosopher cannot be too much on his guard in crediting their relations of things extraordinary, and should never build any hypothesis on anything but clear facts and experiments, or it will be in danger of soon falling, as this does, like a house of cards.

(c) "How many ways there are of kindling fire, or producing heat in bodies! By the sun's rays, by collision, by friction, by hammering, by putrefaction, by fermentation, by mixtures of solids with fluids, and by electricity. And yet the fire when produced, though in different bodies it may differ in circumstances, as in color, vehemence, &c., yet in the same bodies is generally the same. Does not this seem to indicate that the fire existed in the body, though in a quiescent state, before it was by any of these means excited, disengaged, and brought forth to action and to view? May it not constitute a part, and even a principal part, of the solid substance of bodies? If this should be the case, kindling a fire in a body would be nothing more than developing this inflammable principle, and setting it at liberty to act in separating the parts of that body, which then exhibits the appearances of scorching, melting, burning, &c. When a man lights a hundred candles from the flame of one, without diminishing that flame, can it be properly said to have *communicated* all that fire? When a single spark from a flint applied to a magazine of gunpowder, is immediately attended with this consequence, that the whole is in flame, exploding with immense violence, could all this fire exist first in the spark? We cannot conceive it. And thus we seem led to this supposition, that there is fire enough in all bodies to singe, melt, or burn them, whenever it is, by any means, set at liberty, so that it may exert itself upon them, or be disengaged from them. This liberty seems to be afforded it by the passage of electricity through them, which we know can and does, of itself, separate the parts, even of water; and, perhaps, the immediate appearances of fire are only the effects of such separations. If so, there would be no need of supposing that the electric fluid *heats itself* by the swiftness of its motion, or heats bodies by the resistance it meets with in passing through them. They would only be heated in proportion as such separation could be more easily made. Thus a melting heat cannot be given to a large wire in the flame of a candle, though it may to a small one; and this, not because the large wire resists *less* that action of the flame which tends to separate its parts, but because it resists it *more* than the smaller wire, or because the force being divided between more parts acts weaker on each."

(a) Franklin at once acknowledges that the continued depression of the water in the enclosed vessel unquestionably indicates an increase of temperature caused by the passage of the discharge through the air, and that, therefore, the experiment

proves that electricity is capable of producing heat in bodies just like ordinary heat.

(b) The fusion of the metallic wire and the subsequent ignition of the gunpowder show beyond question that electricity produces heat, so that Franklin acknowledges that his former conception of the cold fusion of metals must be abandoned as erroneous. He then compares this result with the case of a lightning stroke recently brought to his attention while in London, in which the bolt melts a bell wire, the fused globules dropping from which burnt holes in the floor of the room on which they fell.

I have included this paragraph as interesting in showing the curious ideas Franklin had at this time respecting the causes of heat.

(c) We find among Franklin's writings on what may properly be regarded as theoretical physics, a comparatively short paper concerning the origin of light. It will be seen from this paper that he was a disbeliever in the Newtonian or corpuscular theory of light; *i. e.*, that light is due to exceedingly minute corpuscles shot off with almost inconceivable rapidity from the surface of the sun, being disposed to accept the Huyghenian theory, that light is produced by undulations or vibrations in an exceedingly tenuous medium that fills all space. This may be seen from the following quotation, taken from a letter written by Franklin, dated April 23, 1752:

"I thank you for communicating the illustration of the theorem concerning light. It is very curious. But I must own I am much in the dark about light. (a) I am not satisfied with the doctrine that supposes particles of matter called light. continually driven off from the sun's surface, with a swiftness so prodigious! Must not the smallest particle conceivable, have with such a motion, a force exceeding that of a twenty-four pounder, discharged from a cannon? Must not the sun diminish exceedingly by such a waste of matter; and the planets, instead of drawing near to him, as some have feared, recede to greater distances through the lessened attraction. Yet these particles, with this amazing motion, will not drive before them, or remove, the least and lightest dust they meet with: And the sun, for aught we know, continues of his ancient dimensions, and his attendants move in their ancient orbits.

(b) "May not all the phenomena of light be more conveniently solved, by supposing universal space filled with a subtle elastic fluid, which, when at rest, is not visible, but whose vibrations affect that fine sense of the eye, as those of air do those the grosser organs of the ear? We do not,

in the case of sound, imagine that any sonorous particles are thrown off from a bell, for instance, and fly in strait lines to the ear; why must we believe that luminous particles leave the sun and proceed to the eye? Some diamonds, if rubbed, shine in the dark, without losing any part of their matter. I can make an electrical spark as big as the flame of a candle, much brighter, and, therefore, visible further; yet this is without fuel; and, I am persuaded, no part of the electric fluid flies off in such case, to distant places, but all goes directly, and is to be found in the place to which I destine it. May not different degrees of the vibration of the above-mentioned universal medium, occasion the appearance of different colours? I think the electric fluid is always the same; yet I find that weaker and stronger sparks differ in apparent colour. some white, blue, purple, red; the strongest, white; weak ones, red. Thus different degrees of vibration given to the air produce the seven different sounds in music, analogous to the seven colours, yet the medium, air, is the same.'

(a) Franklin refers to the tremendous power that the smallest conceivable particle of matter would have if it were shot off from the surface of the sun with the velocity of light. This he agrees with others in regarding as a most serious objection to the corpuscular theory of light. Instead of light possessing the power of demolishing all matter on which it falls, it is unable to move even the lightest dust particle that it falls on.

(b) Franklin simply states here the well known Huygnenian or undulatory theory of light.

Another question that may properly be regarded as belonging to theoretical physics is a belief mentioned by Franklin concerning action at a distance. Like many other philosophers, Franklin rejected the probability of action at a distance, thus writing concerning this matter in a letter which was afterwards read at the Royal Society, November 4th, 1756:

"I agree with you, that it seems absurd to suppose that a body can act where it is not. I have no idea of bodies at a distance attracting or repelling one another without the assistance of some medium, though I know not what that medium is, or how it operates. When I speak of attraction or repulsion, I make use of those words for want of others more proper, and intend only to express only effects which I see, and not causes of which I am ignorant. When I press a blown bladder between my knees, I find I cannot bring its sides together, but my knees feel a springy matter, pushing them back to a greater distance, or repelling them. I conclude that the air it contains is the cause. And when I operate on the air and find I cannot by pressure force its particles into contact, but they still spring back against the pressure, I conceive that there must be some me-

dium between its particles that prevents their closing, though I cannot tell what it is.—And if I were ac-quainted with that medium, and found its particles to approach and recede from each other, according to the pressure they suffered, I should imagine there must be some finer medium between them, by which these operations were performed."

Franklin discovered at a very early date the power possessed by a Leyden jar discharge of imparting permanent magnetism to a steel needle, as well as to its power of reversing the polarity of the magnetic needle. It was known long before Franklin's time that lightning strokes, striking a ship, frequently resulted in a change in the polarity of the magnet.

Franklin thus refers to this phenomenon in a letter to Collinson dated July 27, 1750:

"His compasses lost the virtue of the load-stone, or the poles were reversed; the North point turning to the South.—By electricity we have (*here* at *Philadelphia*) frequently given polarity to needles, and reversed it at pleasure. *Mr. Wilson*, at *London*, tried it on too large masses and with too small force.

"A shock from four large jars, sent through a fine sewing needle, gives it polarity, and it will traverse when laid on water.—If the needle when struck lies East and West the end entered by the electric blast points North. —If it lies North and South the end that lay toward the North will continue to point North when placed on water, whether the fire entered at that end, or at the contrary end.

"The Polarity given is strongest when the needle is struck lying North and South, weakest when lying East and West; perhaps if the force was still greater, the South end, enter'd by the fire, (when the needle lies North and South) might become the North, otherwise it puzzles us to account for the inverting of compasses by lightning; since their needles must always be found in that situation, and by our little Experiments, whether the blast entered the North and went out at the South end of the needle, or the contrary, still the end that lay to the North should continue to point North.

"In these experiments the ends of the needles are sometimes finely blued like a watch-spring by the electric flame.—This colour given by the flash from two jars only, will wipe off, but four jars fix it and frequently melt the needles. I send you some that have had their heads and points melted off by our mimic lightning; and a pin that had its point melted off, and some part of its head and neck run. Sometimes the surface of the body of the needle is also run, and appears blister'd when examined by a magnifying glass: the jars I made use of hold 7 or 8 gallons, and are coated and lined with tin foil; each of them takes a thousand turns of a globe nine inches diameter to charge it."

It is pleasing to record that Franklin did not permit his en-

thusiasm for the great science of electricity to lead him to adopt all kinds of foolish theories concerning its therapeutic and curative powers. There are so many apparently mysterious properties possesed by electricity, that one not possessing a philosophic mind might readily be led to believe almost any statement made concerning the powers of this strange force. It is for this reason that electricity has always been a favorite remedy with quacks and charlatans, possibly in the hopes that, since so little is really known concerning this force, they could the more safely draw on their imagination as regards its cufative powers.

It is true that at the earnest request of many people suffering from paralysis, Franklin consented to treat them by the discharge of the Leyden jar; but, as he afterwards acknowledged, this treatment did not appear to produce any permanent benefits. He thus refers to the matter in a letter written to John Pringle, dated December 21, 1757:

"In compliance with your request, I send you the following account of what I can at present recollect relating to the effects of electricity in paralytic cases, which have fallen under my observation.

"Some years since, when the newspapers made mention of great cures performed in Italy and Germany, by means of electricity, a number of paralytics were brought to me from different parts of Pennsylvania, and the neighbouring provinces, to be electrised, which I did for them at their request. My method was, to place the patient first in a chair, on an electric stool, and draw a number of large, strong sparks from all parts of the affected limb or side. Then I fully charged two six-gallon glass jars, each of which had about three square feet of surface coated; and I sent the united shock of these through the affected limb or limbs, repeating the stroke commonly three times each day. The first thing observed was an immediate greater sensible warmth in the lame limbs that had received the stroke, than in the others; and the next morning the patients usually related, that they had in the night felt a pricking sensation in the flesh of the paralytic limbs; and would sometimes shew a number of small red spots which they supposed were occasioned by those prickings. The limbs, too, were found more capable of voluntary motion, and seemed to receive strength. A man, for instance, who could not the first day lift the lame hand from off his knee, would the next day raise it four or five inches, the third day higher, and the fifth day was able, but with a feeble, languid motion, take off his hat. These appearances gave great spirit to the patients, and made them hope a perfect cure; but I do not remember that I ever saw an amendment after the fifth day; which the patients perceiving, and finding the shocks pretty severe, they became discouraged, went home, and in a short time relapsed; so that I never knew any advantage from elec-

tricity in palsies that was permanent. And how far the apparent temporary advantage might arise from the exercise in the patients journey, and coming daily to my house, or from the spirits given by the hope of success, enabling them to exert more strength in moving their limbs, I will not pretend to say.

"Perhaps some permanent advantage might have been obtained, if the electric shocks had been accompanied with proper medicine and regimen, under the direction of a skillful physician. It may be, too, that a few great strokes as given in my method, may not be so proper as many small ones; since, by the account from Scotland, of a case, in which two hundred shocks from a phial were given daily, it seems, that a perfect cure has been made. As to any uncommon strength supposed to be in the machine used in that case, I imagine it could have no share in the effect produced; since the strength of the shock from the charged glass, is in proportion to the quantity of the glass coated; so that my shocks from those large jars, must have been much greater than any that could be received from a phial held in the hand."

As to the probability of so-called electrical medication; *i. e.*, of causing electrified drugs, placed inside of glass vessels, to be passed through the walls of the vessel into bodies of patients in the shape of medicated effluvia, Franklin expresses himself very decidedly as follows:

"Hence we see the impossibility of success in the experiments proposed, to draw out the effluvial virtues of a non-electric, as cinnamon, for instance, and mixing them with the electric fluid, to convey them with that into the body, by including it in the globe, and then applying friction, &c. For though the effluvia of cinnamon and the electric fluid should mix within the globe, they would never come out together through the pores of the glass, and so go to the prime conductor; for the electric fluid itself cannot come through; and the prime conductor is always supply'd from the cushion, and that from the floor. And besides, when the globe is filled with cinnamon, or other non-electric, no electric fluid can be obtained from its outer surface, for the reason before-mentioned. I have tried another way, which I thought more likely to obtain a mixture of the electric and other effluvia together, if such a mixture had been possible. I placed a glass plate under my cushion, to cut off the communication between the cushion and floor; then brought a small chain from the cushion into a glass of oil of turpentine, and carried another chain from the oil of turpentine to the floor,taking care that the chain from the cushion to the glass, touch'd no part of the frame of the machine. Another chain was fixed to the prime conductor, and held in the hand of a person to be electrised. The ends of the two chains in the glass were near an inch distant from each other, the oil of turpentine between. Now the globe being turned, could draw no fire from the floor through the machine, the communication that way being cut off by the thick glass plate under the cushion: it must then draw it through the chains whose ends were dipped in the oil of turpentine. And

so the oil of turpentine, being an electric per se, could not conduct, what came up from the floor was obliged to jump from the end of one chain to the end of the other, through the substance of that oil, which we could see in large sparks, and so it had a fair opportunity of siezing some of the finest particles of the oil in its passage, and carrying them off with it: but no such effect followed, nor could I perceive the least difference in the smell of the electric effluvia thus collected, from what it has when collected otherwise, nor does it otherwise affect the body of a person electrised. I likewise put into a phial, instead of water, a strong purgative liquid, and then charged the phial, and took repeated shocks from it, in which case every particle of the electric fluid must, before it went through my body, have first gone through the liquid when the phial is charging, and returned through it when discharging, yet no other effect followed than if it had been charged with water."

Franklin's interest in educational matters was not only evidenced by the valuable papers he wrote on such topics, but also by the practical results which flowed from these papers, among which are the establishment of the great University of Pennsylvania, and the American Philosophical Society. I will not stop to discuss these foundations of Franklin, since I have already described them in a paper prepared for publication in the *Journal* of the Franklin Institute. It is interesting, however, to note, in this connection, that there is another character of work for which Franklin was eminently fitted, and in which he might fairly have claimed a place in the first rank; *i. e.*, as a teacher of natural science.

Franklin not only possessed the rare ability of being able to thoroughly understand the causes of natural phenomena, but he also possessed the still rarer ability of being able to impart his ideas concerning such phenomena to others. This, I think, was the natural result of the logical methods employed by Franklin in his scientific investigations. The successive steps taken by him in his experimental researches were never made in a haphazard manner, but invariably followed one another in strict logical sequence, and when he endeavored to impart these principles to others, he always so presented them that the successive steps of his explanation followed the same strict logical order of sequence.

To a certain extent, all of Franklin's letters and papers are properly to be regarded as a species of scientific instruction to the public. The many quotations I have given from some of the more important of these papers will enable one readily to

form an idea as to the clear manner in which they were written. The style of these papers may still be regarded as an admirable example of scientific teaching.

In this connection, we should not lose sight of the important role which the Junto, the select scientific debating and literary society formed by a few of Franklin's immediate friends, played in the development of this side of Franklin's character. The necessity imposed on each of the members of this Society to prepare papers on various topics at more or less regular intervals; to read such papers before the Society; and to take part in the discussion of similar papers prepared by other members, could not have failed to develop any latent powers of teaching that may have been possessed by the different individual members. I think there can be no doubt but that this phase of the Junto greatly improved Franklin's powers in this respect.

An admirable example of Franklin's rare ability as a teacher is to be had in a series of letters on scientific subjects written to a little girl, a Miss S—n, at Wanstead. I will give only a brief quotation from one of these letters, dated May 17, 1760:

"I send my dear, good girl the books I mentioned to her last night. I beg her to accept them as a small mark of my esteem and friendship. They are written in the familiar, easy manner for which the French are so remarkable, and afford a great deal of philosophic and practical knowledge, unembarres'd with the dry mathematics used by more exact reasoners, but which is apt to discourage young beginners.—I would advise you to read with a pen in your hand, and enter in a little book short hints of what you find there that is curious, or that may be useful; for this will be the best method of imprinting such particulars in your memory, where they will be ready, either for practice on some future occasion, if they are matters of utility; or at least to adorn and improve your conversation, if they are rather points of curiosity.—And, as many of the terms of science are such as you cannot have met with in your common reading, and may, therefore be unacquainted with, I think it would be well for you to have a good dictionary at hand, to consult immediately when you meet with a word you do not comprehend the precise meaning of. This may at first seem troublesome and interrupting; but 'tis a trouble that will daily diminish, as you will daily find less and less occasion for your Dictionary as you become more acquainted with the terms; and in the meantime you will read with more satisfaction because with more understanding.—When any point occurs in which you would be glad to have farther information than your book affords you, I beg you would not in the least apprehend that I should think it a trouble to receive and answer your questions. It will be a pleasure, and no trouble. For though I may not be able, out of my own

little stock of knowledge to afford you what you require, I can easily direct you to the books where it may most readily be found."

In this series of letetrs will be found some charming teaching concerning a variety of scientific matters, to which it will be impossible here to do more than briefly refer; for example, why barometers, although placed in rooms with the windows and doors shut, can give the pressure of the outer air; or, even if the windows and doors be open, how can the pressure of the air act on the mercury in an apparently tightly closed vessel; besides other interesting matter which will amply repay a close perusal, on account of the excellent method employed in imparting the information. In one of those letters, Franklin gives his explanation as to the reason of a well-known fact; viz., that it is possible to utilize the power possesed by the skin of abstracting fresh water from the very salt water of the ocean. He calls attention to this matter as follows:

"I have a singular opinion on this subject, which I will venture to communicate to you, though I doubt you will rank it among my whims.—It is certain that the skin has *imbibing* as well as *discharging* pores; witness the effects of a blistering plaister, &c.. I have read that a man hired by a physician to stand by way of experiment in the open air naked during a moist night weighed near three pounds heavier in the morning. I have often observed myself that however thirsty I may have been before going into the water to swim, I am never long so in the water. These imbibing pores, however, are very fine, perhaps fine enough in filtering to separate salt from water; for though I have soaked by swimming, when a boy, several hours a day for several days successively in salt-water, I never found my blood and juices salted by that means, so as to make me thirsty or feet a salt taste in my mouth: And it is remarkable that the flesh of sea fish, though bred in salt water is not salt.—Hence I imagine, that if people at sea, distressed by thirst when their fresh water is unfortunately spent, would make bathing tubs of their empty water casks, and filling them with sea water sit in them an hour or two each day, they might be greatly relieved. Perhaps keeping their cloaths constantly wet might have an almost equal effect, and this without danger of catching cold. Men do not catch cold by wet cloaths at sea. Damp but not wet linen may possibly give colds; but no one catches cold by bathing, and no cloaths can be wetter than water itself. Why damp cloaths should then occasion colds, is a curious question, the discussion of which I reserve for a future letter, or some future conversation."

In his autobiography, Franklin speaks of his fondness for swimming, as well as the fact that, when about twenty years

of age, while at Watt's Printing House, he taught an acquaintance the art of swimming in two lessons. He thus refers to this fact in his autobiography as follows:

"At Watt's printing-house I entracted an acquaintance with an ingenious young man, one Wygate, who, having wealthy relations, had been better educated than most printers; was a tolerable Latinist, spoke French and loved reading. I taught him and a friend of his to swim, at twice going into the river, and they soon became good swimmers. They introduced me to some gentlemen from the country, who went to Chelsea by water, to see the College and Don Saltero's curiosities. In our return, at the request of the company, whose curiosity Wygate had excited, I stripped and leaped into the water and swam from near Chelsea to Blackfriars; performing in the way many feats of activity, both upon and under the water, that surprised and pleased those to whom they were novelties.

"I had from a child been delighted with this exercise, had studied and practised Thevenot's motions and positions, and added some of my own, aiming at the graceful and easy, as well as the useful. All these I took this occasion of exhibiting to the company, and was much flattered by their admiration; and Wygate, who was desirous of becoming a master, grew more and more attached to me on that account, as well as from the similarity of our studies. He at length proposed to me travelling all over Europe together, supporting ourselves everywhere by working at our business. I was once inclined to it, but mentioning it to my good friend Mr. Denham, with whom I often spent an hour when I had leisure, he dissuaded me from it; advising me to think only of returning to Pennsylvania, which he was now about to do."

At a later date, Franklin writes the following as regards the best manner for a person to acquire this art without a teacher:

"I cannot be of opinion with you that 'tis too late in life for you to learn to swim. The river near the bottom of your garden affords a most convenient place for the purpose. And as your new employment requires your often being on the water, of which you have such a dread, I think you would do well to make the trial; nothing being so likely to remove those apprehensions as the consciousness of an ability to swim to the shore, in case of an accident, or of supporting yourself in the water till a boat could come to take you up.

"I do not know how far corks and bladders may be useful in learning to swim, having never seen much trial of them. Possibly they may be of service in supporting the body while you are learning what is called the stroke, or that manner of drawing in and striking out the hands and feet that is necessary to produce progressive motion. But you will be no swimmer until you can place some confidence in the power of the water to support you; I would therefore advise the acquiring of that confidence in the first place; especially as I have known several who by a little of the prac-

tice necessary for that purpose, have insensibly acquired the stroke, taught as it were by nature.

"The practice I mean is this. Chusing a place where the water deepens gradually, walk cooly in until it is up to your breast, then turn round, your face to the shore, and throw an egg into the water between you and the shore. It will sink to the bottom, and be easily seen there, as your water is clear. It must lie in water so deep that you cannot reach it to take it up but by diving for it. To encourage yourself in undertaking to do this, reflect that your progress will be from deeper to shallower water, and that at any time you may, by bringing your legs under you and standing on the bottom, raise your head far above the water. Then plunge under it with your eyes open, throwing yourself towards the egg, and endeavouring by the action of your hands and feet against the water to get forward till within reach of it. In this attempt you will find, that the water buoys you up against your inclination; that it is not so easy a thing to sink as you imagined; that you cannot, by your active force, get down to the egg. Thus you feel the power of the water to support you, and learn to confide in that power; while your endeavours to overcome it and reach the egg, teach you the manner of acting on the water with your feet and hands, which action is afterwards used in swimming to support your head higher above water, or to go forward through it."

In the preceding pages, I have endeavored briefly to give an account of the many departments of physical science that have been covered by the great experimental philosopher whose work I have endeavored to trace. It is a matter of no little regret to me that the many calls of a busy professional life have necessitated my doing this work in so incomplete and hurried a manner. The character of the work that is under review is of such a type that its discussion deserves a much more careful treatment than I have been able to give it. If, however, this work has the effect of attracting a more careful attention to the scientific work of Franklin, I shall feel more than compensated for the labor which even these hurried pages have necessitated. But however imperfect the character of my work, I feel convinced that a careful perusal cannot fail to impress those who are capable of judging work of this character that Benjamin Franklin may be properly regarded,—

(1) As the first great American electrician.

(2) As a natural philosopher of the highest type, both in the domains of geographical physics and applied physics.

(3) As an inventor of the highest type.

Franklin demonstrated his right to the title of the first great American electrician, not only by his famous experiment with

the kite, but also by other electrical work, such as, for example, his single-fluid electrical hypothesis, his masterful analysis of the manner in which the Leyden jar receives and parts with its charge, as well as by the numerous papers on a great variety of electrical subjects to which attention has been briefly called in the preceding pages.

He demonstrated his right to the title of a great natural philosopher by the wonderful skill manifested in investigations on a great variety of physical subjects, to which also attention has been called. The mind of the great master is clearly exhibited in these investigations, not only by the great results achieved, but especially by the logical manner in which the detailed facts were conceived and carried out.

It is especially interesting, in this connection, to bear in mind the great variety of such investigations that were embraced in the field of geographical physics alone, embracing as they did, the causes and phenomena of the aurora borealis, thunder-gusts, waterspouts, whirlwinds, the great northeast storms of the United States, the Gulf Stream, the electrification of clouds, &c.

Franklin's right to the title of one of the greatest of the early American inventors is based on a variety of important work, such, for example, as the invention of the lightning rod, of the Pennsylvania fire-place, of the stove with the inverted draught, of the proper construction of chimneys, the ventilation of buildings and mines, the bifocal spectacles, etc.

I have received through the kindness of Mr. Augustine Biesel of the American Embassy in Paris, through the hands of Mr. Joseph G. Rosengarten, of Philadelphia, a photograph of the Greuze portrait of Franklin, from which the accompanying plate was made.

Before concluding this paper on Franklin, I think it well to give without further comment, the full text of a paper, prepared in Paris, by special request, concerning his great invention of lightning rods. As the inventor of lightning rods, Franklin naturally had his attention repeatedly called to well marked lightning strokes in different parts of the world, so that he had an opportunity of ascertaining in what respects rods erected in accordance with his directions failed in their ability to protect the buildings on which they were placed. We would, conse-

quently expect to find in this paper a much more complete account of Franklin's views on the subject than would be found in his other papers:

"Of Lightning and the Method (now used in America) of securing Buildings and Persons from its mischievous Effects.

"Experiments made in electricity first gave philosophers a suspicion that the matter of lightning was the same with electric matter. Experiments afterwards made on lightning obtained from the clouds by pointed rods, received in bottles, and subjected to every trial, have since proved this suspicion to be perfectly well founded; and that whatever properties we find in electricity, are also the properties of lightning.

"This matter of lightning, or electricity, is an extream subtle fluid, penetrating other bodies, and subsisting in them, equally diffused.

"When by any operation of art or nature, there happens to be a greater proportion of this fluid in one body than in another, the body which has most, will communicate to that which has least, till the proportion becomes equal; provided the distance between them be not too great; or, if it is too great, till there be proper conductors to convey it from one to the other.

"If the communication be through the air without any conductor, a bright light is seen between the bodies, and a sound is heard. In our small experiments we call this light and sound the electric spark and snap; but in the greater operations of nature, the light is what we call lightning, and the sound (produced at the same time, tho' generally arriving later at our ears than the light does to our eyes) is, with its echoes, called thunder.

"If the communication of this fluid is by a conductor, it may be without either light or sound, the subtle fluid passing in the substance of the conductor.

"If the conductor be good and of sufficient bigness, the fluid passes through it without hurting it. If otherwise, it is damaged or destroyed.

"All metals, and water, are good conductors.—Other bodies may become conductors by having some quantity of water in them, as wood, and other materials used in building, but not having much water in them, they are not good conductors, and therefore are often damaged in the operation.

"Glass, wax, silk, wool, feathers, and even wood, perfectly dry are non-conductors: that is, they resist instead of facilitating the passage of this subtle fluid.

"When this fluid has an opportunity of passing through two conductors, one good, and sufficient, as of metal, the other not so good, it passes in the best, and will follow it in any direction.

"The distance at which a body charged with this fluid will discharge itself suddenly, striking through the air into another body that is not charged, or not so highly charg'd, is different according to the quantity of the fluid, the dimensions and form of the bodies themselves, and the state of the air between them.—This distance, whatever it happens to be between

two bodies, is called their striking distance, as till they come within that distance of each other, no stroke will be made.

"The clouds have often more of this fluid in proportion than the earth; in which case as soon as they come near enough (that is, within striking distance) or meet with a conductor, the fluid quits them and strikes into the earth. A cloud fully charged with this fluid, if so high as to be beyond the striking distance from the earth, passes quietly without making noise or giving light; unless it meets with other clouds that have less.

"Tall trees, and lofty buildings, as the towers and spires of churches, become sometimes conductors between the clouds and the earth; but not being good ones, that is, not conveying the fluid freely, they are often damaged.

"Buildings that have their roofs covered with lead, or other metal and spouts of metal continued from the roof into the ground to carry off the water, are never hurt by lightning, as whenever it falls on such a building, it passes in the metals and not in the walls.

"When other buildings happen to be within the striking distance from such clouds, the fluid passes in the walls whether of wood, brick or stone, quitting the walls only when it can find better conductors near them, as metal rods, bolts and hinges of windows or doors, gilding on wainscot, or frames of pictures; the silvering on the backs of looking-glasses; the wires for bells; and the bodies of animals, as containing watery fluids. And in passing thro' the house it follows the direction of these conductors,taking as many in it's way as can assist it in its passage, whether in a strait or crooked line, leaping from one to the other, if not far distant from each other, only rending the wall in the spaces where these partial good conductors are too distant from each other.

"An iron rod being placed on the outside of a building, from the highest part continued down into the moist earth, in any direction strait or crooked, following the form of the roof or other parts of the building, will receive the lightning at its upper end, attracting it so as to prevent its striking any other part; and, affording it a good conveyance into the earth. will prevent its damaging any part of the building.

"A small quantity of metal is found able to conduct a great quantity of this fluid. A wire no bigger than a goose quill, has been known to conduct (with safety to the building as far as the wire was continued) a quantity of lightning that did prodigious damage both above and below it; and probably larger rods are not necessary, tho' it is common in America, to make them of half an inch, some of three-quarters, or an inch in diameter.

"The rod may be fastened to the wall, chimney, &c., with staples of iron.—The lightning will not leave the rod (a good conductor) to pass into the wall (a bad conductor), through those staples.—It would rather, if any were in the wall, pass out of it into the rod to get more readily by that conductor into the earth.

"If the building be very large and expensive, two or more rods may be placed at different parts, for greater security.

"Small, ragged parts of clouds suspended in the air between the great body of clouds and the earth (like leaf gold in electrical experiments), often serve as partial conductors for the lightning, which proceeds from one of them to another, and by their help comes within the striking distance to the earth or a building. It therefore strikes through those conductors a building that would otherwise be out of striking distance.

"Long, sharp points, communicating with the earth, and presented to such parts of clouds, drawing silently from them the fluid they are charged with, they are then attracted to the cloud, and may leave the distance so great as to be beyond the reach of striking.

"It is therefore that we elevate the upper end of the rod six or eight feet above the highest part of the building, tapering it gradually to a fine, sharp point, which is gilt, to prevent its rusting.

"Thus the pointed rod either prevents a stroke from the cloud, or, if a stroke is made, conducts it to the earth with safety to the building.

"The lower end of the rod should enter the earth so deep as to come at the moist part, perhaps two or three feet; and if bent when under the surface so as to go in a horizontal line six or eight feet from the wall, and then bent again downwards three or four feet, it will prevent damage to any of the stones of the foundation.

"A person apprehensive of danger from lightning, happening in the time of thunder to be in a house not so secured, will do well to avoid sitting near the chimney, near a looking-glass or any gilt pictures or wainscot; the safest place is in the middle of the room, (so it be not under a metal lustre suspended by a chain) sitting in one chair and laying the feet up in another. It is still safer to bring two or three mattrasses or beds into the middle of the room, and folding them up double, place the chair upon them; for they not being so good conductors as the walls, the lightning will not chuse an interrupted course through the air of the room and the bedding, when it can go thro' a better continued conductor, the wall. But where it can be had, a hammock or swinging bed, suspended by silk cords equally distant from the walls on every side, and from the ceiling and floor above and below, affords the safest situation a person can have in any room whatever; and what indeed may be deemed quite free from danger by any stroke by lightning."

Franklin died on the 17th of April, 1790. The Congress of the United States, which was in session at the time of his death, passed the following resolution on the receipt of the sad news:

"The House, being informed of the decease of Benjamin Franklin, a citizen whose native genius was not more an ornament to human nature than his various exertions of it have been precious to science, to freedom, and to his country, do resolve, as a mark of the veneration due to his memory that the members wear the customary badge of mourning for one month."

A higher honor was paid to his memory by the National As-

sembly of France on the morning after the intelligence reached Paris, on June 11. The assembly was convened, when Mirabeau spoke as follows:

"Franklin is dead! The genius, that freed America and poured a flood of light over Europe, has returned to the bosom of the Divinity.

"The sage whom two worlds claim as their own, the man for whom the history of science and the history of empires contend with each other, held, without doubt, a high rank in the human race."

"Too long have political cabinets taken formal note of the death of those who were great only in their funeral panegyrics. Too long has the etiquette of courts prescribed hypocritical mourning. Nations should wear mourning only for their benefactors. The representatives of nations should recommend to their homage none but the heroes of humanity.

"The Congress has ordained, throughout the United States, a mourning of one month for the death of Franklin; and, at this moment, America is paying this tribute of veneration and gratitude to one of the fathers of her Constitution.

"Would it not become us, Gentlemen, to join in this religious act, to bear a part in this homage, rendered, in the face of the world, both to the rights of the man, and to the philosopher who has most contributed to extend their sway over the whole earth? Antiquity would have raised altars to this mighty genius, who, to the advantage of mankind, compassing in his mind the heavens and the earth, was able to restrain alike thunderbolts and tyrants. Europe, enlightened and free, owes at least a token of remembrance and regret to one of the greatest men who have ever been engaged in the service of philosophy and of liberty.

"I propose that it be decreed, that the National Assembly, during three days, shall wear mourning for Benjamin Franklin."

On the adoption of this motion by acclamation, the Assembly decreed that on the 14th day of June, they would go into mourning for three days, and directed the President of the Assembly to write a letter of condolence to the Congress of the United States.

It has been falsely alleged that Franklin was an irreligious man. An assertion of this kind surely could not have been made by anyone conversant with Franklin's writings. I will merely quote a letter written by Franklin, on March 9, 1790, shortly before his death, in which he says:

"You desire to know something of my religion. It is the first time I have been questioned upon it. But I cannot take your curiosity amiss, and shall endeavour in a few words to gratify it. Here is my creed: I believe in one God, the creator of the universe. That he governs it by his Providence. That he ought to be worshipped. That the most accept-

able service we render to him is doing good to his other children. That the soul of man is immortal, and will be treated with justice in another life respecting its conduct in this. These I take to be the fundamental points in all sound religion, and I regard them as you do in whatever sect I meet with them."

If, however, this testimony had been wanting, or if anyone should allege that this was merely the opinion of a man who had nearly reached the end of his life, the following epitaph prepared by Franklin, when at the age of but twenty-three years, would prove the incorrectness of the conclusion:

"The Body
Of
Benjámin Franklin.
Printer,
(Like the cover of an old book,
Its contents torn out,
And stript of its lettering and gilding,)
Lies here, food for worms.
But the work shall not be lost,
For it will, as he believed, appear once more,
In a new and more elegant edition,
Revised and corrected
By
The Author."

THE ALUMINUM INDUSTRY AND THE HALL PATENT.

Of no little significance to the aluminum industry in the United States was the expiration on April 2, 1906, of the patent of Charles M. Hall, granted on April 2, 1889, and under which it has been possible for the Pittsburgh Reduction Company to maintain almost a monopoly of production in the United States. Recently the demand has been so heavy that this company has not been able to keep up with it and domestic consumers have turned to Europe, but even at the high prices paid abroad it has not been possible to obtain any considerable quantities. The large requirements of the automobile industry are responsible chiefly for the expansion in the demand in recent years. Referring to the expiration of the Hall patent and its effect on aluminum manufacture the *Metal Industry* makes the following interesting statement:

It will be remembered that this patent, which became of fundamental importance for the commercial production of aluminum, protected the use of an electrolyte composed of cryolite as a solvent for bauxite, and this electrolyte had the most important property of being easily fusible. The

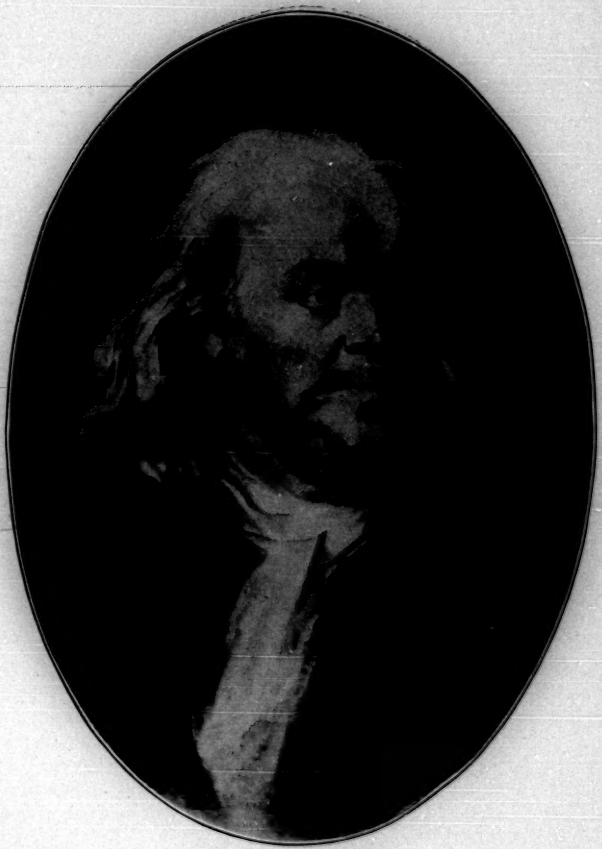
extension of the manufacture of aluminum followed and the three-cornered litigation about patent rights between the Pittsburgh Reduction Company, as owners of the Hall patent, and the Electric Smelting & Aluminum Company, the moving spirits of which were the well-known pioneers in the aluminum industry, the Cowles brothers, as owners of the Bradley patent, and, in the third place, Grosvenor P. Lowrey.

There is no doubt that owing to the scarcity and high price of the metal efforts will be made to start competing works after the Hall electrolyte becomes public property, and in fact there are many rumors of such proceedings already in the air. As far as the Pittsburgh Reduction Company itself is concerned, it must be remembered that though its electrolyte is public property, yet its method of operation is protected by the Bradley patent, which will not expire until February, 1909. The Bradley patent is of fundamental importance for the manufacture of aluminum, covering as it does the use of the current, as well for the purpose of keeping the electrolytic bath in a molten condition as for effecting its decomposition and setting the aluminum free at the cathode. I has been claimed variously that Mr. Hall never succeeded in producing aluminum commercially until he abandoned the method of conducting the electrolysis in a vessel heated from the outside by an exterior source of heat. If fthat holds true it seems to be very difficult for other people to get around the claims of the Bradley patent, in spite of their having an electrolyte of the proper nature. Moreover, the Pittsburgh Reduction ompany has the immense advantage over its competitors of a large, well equipped plant, trained workmen and an experience of a number of years' duration, and is making strenuous efforts to enlarge its productive capacity.

What in view of the above considerations will be the future development of the aluminum industry is difficult to say. No doubt if competition should be successful the price of the metal would fall to a greater or less extent. As far as the Pittsburgh Reduction Company is concerned it must be said that it has never abused the privilege of having a monopoly for the purpose of putting a prohibitory price on the metal.

TIN IN NEW SOUTH WALES.

At Tingha, in the Inverell district, New South Wales, there are fifteen or sixteen dredges working for tin, all doing well. They are reported to have from six to ten years' work in front of them. The development of some of the lodes and deep leads of the district is urged. According to E. F. Pittman, the geological conditions of the district are almost precisely similar to those of Cornwall.



BENJAMIN FRANKLIN
(After Greuze.)

OBERLIN
COLLEGE
LIBRARY.

Benjamin Franklin Trust Funds to the Cities of Boston and Philadelphia.

By Dr. Edwin James Houston.

Emeritus Professor of Physics in the Franklin Institute.

Some time before his death, in 1790, Benjamin Franklin, remembering the necessity that had existed in his own case for obtaining a loan of money from two of his friends in order to be able to set up his business as a printer, placed in a codicil to his last will and testament, dated June 23rd, 1789, a legacy to each of the cities of Philadelphia and Boston the sum of 1000 pounds sterling. In the case of Boston this sum was to be managed under the direction of the Selectmen, together with the ministers of the oldest Episcopalian, Congregational and Presbyterian Churches in that town. This sum was to be loaned to such young married artificers, less than twenty-five years of age, who had faithfully served an apprenticeship in Boston, and who could obtain, not only a good moral character from two respectable citizens, but who could induce them to become sureties in a bond with the applicant for the repayment of the money, together with interest.

The conditions of such loans were as follows: The amount of the loan was not to exceed the sum of sixty pounds to each person, nor was it to be less than fifteen pounds. Interest was to be paid at the rate of 5% per annum.

In order to render the making of the repayments easier to the borrowers, Franklin imposed the condition that each borrower should be obliged to pay with the yearly interest one-tenth part of the principal, and the sum of principal and interest so paid to be again loaned out to others.

Recognizing, as Franklin did, the rate of increase of capital when left at compound interest, he calculated that at the end of the first hundred years the £1000 would have increased to

£131,000. He left directions to those in charge of the fund that as soon as this period of time had elapsed, they were to lay out, at their discretion, £100,000 in public works, such, for example, as fortifications, bridges, aqueducts, public buildings, baths, pavements, or whatever might make living in the town more convenient to its people and render it more agreeable to strangers resorting hither for health or temporary residence. The remaining £31,000, he directed to be loaned out on interest under the original conditions for another hundred years. At the end of this second term of one hundred years, Franklin estimated that the sum would have reached the amount of £4,000,061, of which £1,000,061 were to be placed at the disposal of the inhabitants of the town of Boston, and £300,000,000 at the disposal of the Government of the State, "not presuming to carry my views further," as the will naively remarks.

The fund left to the City of Philadelphia was placed under the same general conditions as that left to the City of Boston, with, however, the exception that since the City of Philadelphia was incorporated, the fund was to be placed directly under the management of the corporation.

In looking into the conditions of the City of Philadelphia at the end of the first hundred years that were to elapse from the formation of the trust, and bearing in mind the probability of the contamination of the sources of drinking water of a city like Philadelphia, Franklin recommended that at this time the sum of £100,000 be expended for the purpose of bringing the waters of Wissahickon Creek into the town, so as to supply the inhabitants with pure water. This he thought there should be no difficulty in doing by means of a general gravity system, or, if such was insufficient for any portion of the city, a reservior could be built so as to raise the level of the water by means of a dam. He also recommended that the Schuylkill River should be made completely navigable with, presumably, the balance of the fund. At the end of the second hundred years, he directed that the sum of £4,000,061 be divided between the inhabitants of the City of Philadelphia and the Government of Pennsylvania, in a similar manner as he had directed as regards the similar legacy to the City of Boston.

We here publish in full the text of this part of Franklin's remarkable will, throwing as it does additional light on the character of the man, as well as on the plan that his benevolence had devised:

" * * * I have considered that, among artisans, good apprentices are most likely to make good citizens, and, having myself been bred to a manual art, printing, in my native town, and afterwards assisted to set up my business in Philadelphia by kind loans of money from two friends there, which was the foundation of my fortune, and of all the utility in life that may be ascribed to me, I wish to be useful after death, if possible, in forming and advancing other young men, that may be serviceable to their country in both those towns. To this end, I devoted two thousand pounds sterling, of which I give one thousand thereof to the inhabitants of the town of Boston, in Massachusetts, and the other thousand to the inhabitants of the City of Philadelphia, in trust, to and for the uses, intents and purposes hereinafter mentioned and declared.

"The said sum of one thousand pounds sterling, if accepted by the inhabitants of the town of Boston, shall be managed under the direction of the selectmen, united with ministers of the oldest Episcopalian, Congregational and Presbyterian churches in that town, who are to let out the same upon interest, at five per cent. per annum, to such young married artificers, under the age of twenty-five years, as have served an apprenticeship in the said town, and faithfully fulfilled the duties required in their indentures, so as to obtain a good moral character from at least two respectable citizens, who are willing to become their sureties, in a bond with the applicants, for the repayment of the moneys so lent, with interest, according to the terms hereinafter prescribed; all of which bonds are to be taken for Spanish milled dollars, or the value thereof in current gold coin; and the managers shall keep a bound book or books, wherein shall be entered the names of those who shall apply for and receive benefits of this institution, and of their sureties, together with the sums lent, the dates, and other necessary and proper record respecting the business and concerns of this institution. And, as these loans are intended to assist young married artificers in setting up their business, they are to be proportioned by the discretion of the managers, so as not to exceed sixty pounds sterling to one person, nor to be less than fifteen pounds, and, if the number of appliers so entitled should be so large that the sum will suffice to afford to each as much as might otherwise not be improper, the proportion to each shall be diminished so as to afford to every one some assistance. These aids may, therefore be small at first, but, as the capital increases by the accumulated interest, they will be more ample. And, in order to serve as many as possible in their turn, as well as to make the payment of the principal borrowed more easy, each borrower shall be obliged to pay, with the yearly interest, one-tenth part of the principal, which sum of principal and interest so paid in, shall be again let out to fresh borrowers.

"And, as it is presumed that there will always be found in Boston virtu-

ous and benevolent citizens willing to bestow a part of their time in doing good to the rising generation, by superintending and managing this institution gratis, it is hoped, that no part of the money will at any time be dead, or be diverted to other purposes, but be continually augmenting by the interest, in which case there may, in time, be more than the occasions in Boston shall require, and then some may be spared to the neighboring or other towns, in the said State of Massachusetts, who may desire to have it; such town engageing to pay punctually the interest and the portions of the principal, annually, to the inhabitants of the town of Boston.

"If this plan is executed, and succeeds as projected without interruption for one hundred years, the sum will then be one hundred and thirty thousand pounds, of which I would have the managers of the donation of the town of Boston then lay out, at their discretion, one hundred thousand pounds in public works, which may be judged of most general utility to the inhabitants, such as fortifications, bridges, aqueducts, public buildings, baths, pavements, or whatever may make living in the town more convenient to its people, and render it more agreeable to strangers resorting thither for health or a temporary residence. The remaining thirty-one thousand pounds I would have continued to be let out on interest, in the manner above directed, for another hundred years, as I hope that it will have been found that the institution has had a good effect on the conduct of youth, and been a service to many worthy characters and useful citizens. At the end of this second term, if no unfortunate accident has prevented the operation, the sum will be four millions and sixty-one thousand pounds sterling, of which I leave one million sixty-one thousand pounds to the disposition of the inhabitants of the town of Boston, and three millions to the disposition of the government of the State, not presuming to carry my views farther.

"All the directions herein given respecting the disposition and management of the donation to the inhabitants of Boston, I would have observed respecting that to the inhabitants of Philadelphia, only, as Philadelphia is incorporated, I request the corporation of that city to undertake the management agreeably to the said direction, and I do hereby vest them with full and ample powers for that purpose. And, having considered that the covering a ground plat with buildings and pavements, which carry off most of the rain, and prevent it soaking into the earth and renewing and purifying the springs, whence the waters of the wells must gradually grow worse, and in time be unfit for use, as I find has happened in all old cities, I recommend that at the end of the first hundred years, if not done before, the corporation of the city employ a part of the one hundred thousand pounds in bringing, by pipes, the water of Wissahickon Creek into the town, so as to supply the inhabitants, which I apprehend may be done without great difficulty, the level of that peak being much above that of the city, and may be made higher by a dam. I also recommend making the Schuylkill completely navigable. At the end of the second hundred years I would have the disposition of the four million and sixty-one thousand pounds divided between the inhabitants of the City of Philadelphia and the government of

Pennsylvania, in the same manner as herein directed with respect to that of the inhabitants of Boston and the government of Massachusetts.

"It is my desire that this institution should take place and begin to operate within one year after my decease, for which purpose due notice should be publicly given previous to the expiration of that year, that those for whose benefit this establishment is intended may make their respective applications. And I hereby direct my executors, the survivors or survivor of them, within six months after my decease to pay over the said sum of two thousand pounds sterling to such persons as shall be duly appointed by the selectment of Boston and the corporation of Philadelphia to receive and take charge of their respective sums, of one thousand pounds each, for the purpose aforesaid.

"Considering the accidents to which all human affairs and projects are subject in such a length of time, I have, perhaps, too much flattered myself with a vain fancy that these dispositions, if carried into execution, will be continued without interruption and have the effect proposed. I hope, however, that if the inhabitants of the two cities should not think fit to undertake the execution, they will, at least, accept the offer of these donations as a mark of my good will, a token of my gratitude and a testimony of my earnest desire to be useful to them after my departure. I wish, indeed, that they may both undertake to endeavor the execution of the project, because I think that, though unforseen difficulties may arise, expedients will be found to remove them, and the scheme be found practicable. If one of them accept the money, with the conditions, and the other refuses, my will then is that both sums be given to the inhabitants of the city acepting the whole, to be applied to the same purposes, and under the same regulations directed for the separate parts; and, if both refuse, the money, of course, remains in the mass of my estate, and is to be disposed of therewith according to my will made the seventeenth of July, 1788."

But Benjamin Franklin did not begin to appreciate the wonderful rate of increase that was destined to the growth of the United States in general, or of the City of Philadelphia in particular. During these first hundred years, the City of Philadelphia has so far exceeded its area as to actually include the parts of the very Wissahickon Creek that were to form the source of the pure water supply for the inhabitants, uncontaminated by reason of its distance from the city. The $500,000, large as it seemed to Franklin, would have been entirely too small to permit of what Franklin thought would constitute a complete water system. In point of fact, the reading of the public newspapers of the present time, would show how much money Philadelphia contemplates spending on its great filtration system, so that, as can now easily be seen, the expenditure of the entire amount would have formed but a small fractional part

of the sum required for such purposes, thus leaving entirely out of consideration the ensuring of the navigability of the Schuylkill River, or even the Delaware.

Speaking now of the legacy to the City of Philadelphia alone, it will be interesting to note the growth of the original sum of £1000 above referred to. The actual value of the invested legacy at different periods, as taken from the original records of the trust, are as follows:

Original Legacy, 1,000 pounds sterling	$ 5,000
Value of Legacy Dec. 31, 1854,	20,600
" " " " 1870	38,900
" " " " 1880	62,350
" " April 17, 1890	87,600.29
" " Dec. 31, 1890	89,900
" " " " 1900	136,600
" " " " 1905	159,000

It will be observed that on the 17th day of April, 1890, exactly one hundred years after the death of Benjamin Franklin, the value of this trust fund in the case of the City of Philadelphia reached the sum of only $87,600.29, while the amount on December 31, 1905, was only $159,000.

A number of circumstances have combined to bring about the discrepancy between the theoretical and the actual value of the sum at the end of the first hundred years. In the first place, as is well known, in order to ensure the great increase that is possible in the case of money placed at compound interest, it is of course necessary that no lapse shall exist in the earning power of the money; in other words, that no loss shall occur either in the case of the principal or of the interest. This, of course, necessitates a continuance of the best financial management, together with no failures as regards the recovery of either principal or interest.

Whatever may have been the reasons, it is a matter of fact that the number of apprenticed artisans applying for the loan was comparatively small. The last loan made from the City of Philadelphia fund was made in the year 1885, and since that time, no application for a loan has been received. The reasons for this are probably as follows:

(1) There are now comparatively few indentured apprentices in the City of Philadelphia.

(2) The loan of money on the mere recommendation of two citizens cannot be regarded as sound financial policy. Consequently, a real estate security is required. Where, however, real estate security is available, the trust companies and building associations are capable of offering equally attractive, if not, indeed, more attractive terms.

It is interesting to note that in March, 1895, the balance of the Franklin fund available for public improvements was appropriated by the proper authorities towards the erection of a Museum and Art Gallery in Fairmount Park. The following minute of this fact is taken from the 26th Annual Report of the Board of Directors of City Trusts, for the year 1895:

"The question of the expenditure of that portion of the Benjamin Franklin Fund available since the expiration of the first one hundred years named in the will, has been finally settled by the acceptance, by the Commissioners of Fairmount Park, of the amount, $84,285.02, to be expended in the erection of an Art Gallery to be located in the Park, that portion of the building so paid for to have the name of Benjamin Franklin connected with it in such a manner as to serve to perpetutate his memory."

On May 11th, 1895, this appropriation was accepted by the Park Commissioners, but up to the present date, January, 1906, nothing further has been done in this direction, no money has been expended, and the funds still remain in the hands of the Board of Directors of City Trusts, invested and drawing income.

It is interesting to note than on the 27th of September, 1890, proceedings were commenced in the Orphans' Court of the City of Philadelphia to have the Franklin Trust Fund declared invalid. These proceedings were based on a petition in behalf of Albert D. Bache, a great-great-grandchild of Benjamin Franklin. This petition was presented to the Orphans' Court of Philadelphia County, alleging that the trust created by the said codicil to the will was void,

"(a) Because an accumulation was directed for a longer period than was allowed by the common law.

"(b) Because the legacy to the City of Philadelphia and the State of Pennsylvania vested at a period after the testator's death beyond that allowed by the law of this State.

"(c) Because the use of the said funds during the first hundred years after the testator's death was not a charitable use.

"(d) Because the purpose contemplated by the testator has become impossible on account of the dereliction and negligence of the trustees in not realizing the anticipated sum.

"And praying for an account.

"On the 28th day of October, 1890, a demurrer on behalf of the City of Philadelphia, trustee, was filed, setting forth:

"(a) That petitioner was barred by lapse of time,

"(b) That the legacy was valid.

"(c) That the trust was a charity.

"(d) That the Orphans' Court had no jurisdiction."

A similar petition was made on November 15th, 1890, on behalf of Elizabeth D. Gillespie.

The decision of the Orphans' Court on these petitions was that the trust was valid and a charity, and should not be set aside, or, quoting a part of the language of the Court:

"The City of Philadelphia is something more than a mere legatee, it is a purchaser for value; or, to speak more accurately, it has, at the earnest request of the testator and upon his promise to pay a certain reward, performed arduous services, for his benefit or gratification, or the benefit, at his instance, of third person, during a stipulated time. The contract so made is binding upon the original promiser, and no less upon those succeeding to his estate.

"The petitions are dismissed."

On a subsequent appeal to the Supreme Court, the decision of the Orphans' Court was affirmed.

On December 2, 1892, a bill in equity was filed in the Court of Common Pleas, No. 4, of Philadelphia County, on behalf of Elizabeth D. Gillespie, administratrix of the estate of Benjamin Franklin and of Richard Bache, deceased, against the City of Philadelphia, Trustee. The decision of the Court was, however, against the complainant. Quoting from a part of the decision:

"On the whole case we are of opinion that Dr. Franklin has established in legal form three valid, benevolent and beneficial charities, neither one of which is vulnerable when assaulted upon any of the grounds which were argued before us.

"We therefore, sustain the demurrer of the defendants, and dismiss the plaintiff's bill with costs."

Such, in brief, is the history of the Trust Fund created by

Franklin, and placed in the control of the City of Philadelphia. While it did not attain the magnificent proportions that its great benefactor hoped, yet it can, by no means, be regarded as having entirely failed in its benevolent purposes.

It is an interesting matter in this connection to note that the Franklin Fund received an addition at the hands of John Scott, Chemist, of St. Patrick's Square, in the City of Edinburgh, Scotland, who appointed James Ronaldson, of Philadelphia, Typefounder, as his true and lawful attorney, for him and in his name, as sole executor to transfer the sum of $3000 of certain stock to the Corporation of Philadelphia, which was entrusted with the management of the late Dr. Franklin's legacy, to be applied to the same purposes as the legacy.

Moreover, the same John Scott transferred a further sum of $4000 to the City of Philadelphia, to be placed with the same management as the said Dr. Franklin's legacy, with, however, the proviso that the interest and dividends to become receivable upon such sum be laid out in premiums to be distributed among ingenious men and women who make useful inventions; that no such premium shall exceed $20, and that with the same shall be given a copper medal, with the inscription "To the most deserving." This legacy, known as the John Scott Medal Legacy, is now, so far as the recommending of the prizes is concerned, in the hands of the Franklin Institute of the State of Pennsylvania. The medal is awarded by the Board of Directors of City Trusts, but that Board depends absolutely upon a recommendation of the Franklin Institute, and has never failed to award as recommended, nor award unless so recommended.

THE METRIC SYSTEM IN THE UNITED STATES.

An informal address by Dr. A. G. Bell to the Committee on Coinage, Weights, and Measures of the U. S. House of Representatives, on February 16, giving an explanation of the reasons why the United States should abandoned its heterogeneous systems of weights and measures, is printed in the *National Geographic Magazine* for March. The committee had under consideration a bill before Congress proposing that, from July 1, 1908, all the departments of the government of the United States, in the transaction of business requiring the use of weight and measurement, shall employ and use the weights and measures of the metric system. Dr. Bell gave an exhaustive account of the anomalies of the British systems of measurements in use in the United States. He pointed out that all civilized countries, with the exception of the United States and Great Britain and her colonies, have adopted the similar and more scientific decimal system. He reminded the committee that the metric system was legalized in the United States in 1866, and that its adoption by a portion of the population had increased the present confusion. By reference to the decimal system of coinage already in use in the States, Dr. Bell proved convincing instances of the simplification possible with it in the conversion of units, and explained that the United States, when it changed from the old system of pounds, shillings and pence to the present dollars and cents, did not adopt the metric system of weights and measures because the latter, as we know it, did not appear until after the American Coinage Act of 1792. The facts that our whole system of arithmetic is decimal, that no difficulty whatever is experienced by ordinary workmen in the use of the metric system—provided there is no question of converting their measurements—and that the use of the metric system need not mean the use of new tools, were all very clearly explained. It is interesting to note, in connection with this Bill before Congress, that the committee on publicity of the Metrological Society, of which Prof. Simon Newcomb is chairman, has circulated a letter urging all persons in favor of the introduction of the metric system to write, and also secure from other friends, as many letters to representatives in Congress as possible, so that they may see that public sentiment is in the direction of the adoption of decimal weights and measures.

A THERMIT REPAIR.

An interesting thermit repair was recently accomplished by L. Heynemann, consulting engineer, at San Francisco, Cal., upon a large forged steel dredge bucket arm measuring two inches thick by twelve and one-half inches wide at the break. The fracture was complete. To facilitate the flow

of theremit steel through and between the broken parts a number of holes were drilled in the crack. A sheet-iron mold box was first closely fitted to the arm and carefully lined with sand and flour core mixture and thoroughly baked. After the mold was placed in position the parts were heated by a blow torch to expel moisture and avoid chilling the thermit steel.

The thermit reaction produces a temperature of approximately 5400 degrees F., so that, as in this instance, it is possible to add to the contents of the crucible a considerable percentage of steel punchings or rivets, which somewhat lowers the temperature and increases the quantity of liquid steel. Two hundred and fifty pounds of thermit were used (yielding after combustion 125 pounds of liquid steel and 125 pounds of slag) and 40 pounds of small steel rivets. On the completed repair a reinforcing collar of thermit steel was cast around the weld to give extra strength.

Tests covering the strength and permanency of thermit welds were recently made at the works of the Fore River Shipbuilding Company, Quincy, Mass. Bars of rolled steel two inches by four and one-half inches were drilled, broken and welded with thermit, and standard test bars cut from the center of the weld. As a basis of comparison, test bars were also cut from the unwelded portions of the stock. The following gives the gist of the results obtained:

Description.	Elastic limit.	Tensile strength.
Weld	32,000	59,000
Stock	38,500	60,500
Weld	33,700	61,800
Stock	36,850	63,400

As an average of the two cases, it will be noticed that the elastic limit suffers a reduction of about 12.7 per cent. after the welding, but only about 2.5 per cent. of the tensile strength is lost.—*Iron Age.*

Sections.

Section of Photography and Microscopy.—*Stated Meeting*, held Thursday, March 1, 1906. Dr. Henry Leffmann in the chair. Present, seventy-two members and visitors.

The first communication of the evening was made by Prof. Henry Kraemer, of the Philadelphia College of Pharmacy, entitled "Some Experiments in Growing and Photographing Wild Plants." The speaker's remarks were profusely illustrated with the aid of lantern pictures.

The subject was discussed by the chairman, and Messrs. Ridpath and Wilbert.

The thanks of the meeting were tendered to Prof. Kraemer. Adjourned.

M. I. Wilbert, *Secretary.*

Stated Meeting held Thursday, April 19, 1906. Dr. Henry Leffman in the chair. Present, fifteen members and visitors.

Dr. Leffmann presented the first communication of the evening on "Invisible Micro-organisms."

Mr. John Bartlett followed with a paper on "Modified Form of Reduction by Farmer's Method." (Referred for publication.)

M. I. WILBERT, *Secretary.*

ELECTRICAL SECTION.—A *stated meeting* of the Electrical Section was held on Thursday, March 22, at 8 P.M. President Thos. Spencer in the chair.

The minutes of the last regular meeting were read and approved. There being no items of business, the paper of the evening on "The Mercury Arc," by Dr. E. Weintraub, of the Research Laboratory of the General Electric Company of Schenectady, N. Y., was proceeded with.

This paper treated the subject from the standpoint of the development of the Mercury Arc, and was fully illustrated with experiments, showing both the principles employed, and the practical application of the arc.

On motion a vote of thanks was extended to Dr. Weintraub for his very instructive and interesting lecture.

There were fifty members present. On motion the meeting adjourned.

GEO. A. HOADLEY, *Secretary pro tem.*

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, April 5, 8 P.M. Mr. James Christie in the chair. Present, 110 members and visitors.

The paper of the evening was read by Mr. Chas. G. Darrach, of Philadelphia, on "The Equipment and Maintenance of the Modern Community Building."

The subject was freely illustrated with the aid of lantern photographs, and was discussed by Prof. H. W. Spangler, and Messrs. C. A. Hexamer, Francis Head and James Christie. Adjourned.

FRANCIS HEAD, *Secretary.*

Stated Meeting, held Thursday, April 26, 8 P.M. President Chas. Day in the chair. After the transaction of formal business, the chairman introduced the speaker of the evening, Mr. Strickland L. Kneass, of Wm. Sellers & Co., Philadelphia, who read a highly interesting and instructive paper on "High Pressure Steam Tests of a Locomotive Injector," which was freely illustrated with the aid of latern photographs.

The subject was discussed by Mr. Henry F. Colvin, the chairman, and the author, and the paper was referred for publication.

The thanks of the meeting were voted to the speaker. Adjourned.

WM. H. WAHL, *Sec'y pro tem.*

SECTION OF PHYSICS AND CHEMISTRY.—*Stated Meeting*, held Thursday, March 29th, at 8 P.M. Dr. Robert H. Bradbury in the chair. Present, thirty members and visitors.

The paper of the evening was read by Prof. E. L. Nichols, of Cornell University. The subject covered the phenomena of Phosphorescence and Fluorescence. The speaker's remarks were profusely illustrated.

The subject was discussed by Dr. H. H. Heyl, Dr. Geo. S. Stradling, Mr. Carl Hering and others.

The thanks of the meeting were voted to the speaker of the evening. Adjourned.

E. A. PARTRIDGE, *Secretary.*

Stated Meeting, held Thursday, April 12, 8 P.M. Dr. Edward Goldsmith in the chair. Present, twenty members and visitors.

Mr. Lyman F. Kebler, of the U. S. Dept. of Agriculture, read the paper of the evening, on "Drugs and Chemicals." The speaker called attention to the universal impurity of chemicals, even of those marked C. P., by reputable manufacturers. He referred also to a similar condition in the case of drugs, and to their gross abuse, as a public scandal. The speaker received a vote of thanks. Adjourned.

EDWD. A. PARTRIDGE, *Secretary.*

Franklin Institute.

(Proceedings of the Stated Meeting held Wednesday, March 21, 1906.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 21, 1906.

PRESIDENT JOHN BIRKINBINE in the chair.

Present, 132 members and visitors.

The report of the Board of Managers exhibited the election of eight new members.

The first communication of the evening was presented by Mr. Herbert E. Ives, of Johns Hopkins University, on "An Improved Process of Diffraction Color Photography."

The speaker illustrated his remarks by means of lantern photographs and specimen color photographs made by the process.

The subject was referred for investigation to the Committee on Science and the Arts.

Mr. U. C. Wanner gave an interesting informal address on "The Photography of Flowers," illustrated by numerous flower pictures very artistically executed and colored in imitation of nature.

The appointment of President Birkinbine by the Board of Managers to represent the Institute at the bi-centennial anniversary of the birth of Franklin, to be celebrated on April 17-20, by the American Philosophical Society, was announced and confirmed.

WM. H. WAHL, *Secretary.*

(Proceedings of the Stated Meeting held Wednesday, April 18, 1906.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 18, 1906.

PRESIDENT JOHN BIRKINBINE in the chair.

Present, eighty-two members and visitors.

Addition to membership since last report, six.

The first communication of the evening was read by Mr. W. S. Ayers, Mining Engineer, of Hazleton, Pa., describing the recently-discovered Deutschman Cave, in the Silkirk Mountains of Canada. The communication was profusely illustrated with the aid of lantern pictures.

Mr. John C. Troutwine followed with an account of the Aqueduct of Philadelphia's First Water Works as uncovered by the excavation for the Subway of the Philadelphia Rapid Transit Co., on South Penn Square, opposite to the South Entrance to City Hall.

The meeting was closed by Mr. W. W. Jennings, who exhibited and described a series of photographs taken by him during a recent visit to Mt. Vesuvius.

Adjourned.

WM. H. WAHL, *Secretary.*

Committee on Science and the Arts.

(Abstract of Proceedings of Stated Meeting held Wednesday, April 11, 1906.)

MR. HUGO BILGRAM in the chair.

The following reports were adopted:

(No. 2358.) *Browning's Automatic Pistols.* Colt's Patent Fire-Arms Mfg. Co, Hartford, Conn.

ABSTRACT: A supplementary report. In the original report on this invention, approved May 5th, 1905, it was stated that the Browning weapon examined by the Committee did not function properly with soft-pointed bullets as the slide jammed and refused to close automatically.

In consequence of this objection, the inventor submitted to the Committee an improved pistol—thirty-eight calibre military model—which in the hands of the chairman functioned quite satisfactorily with 100 soft-pointed cartridges. *(Sub-Committee,* Wm. O. Gregg, Chairman.)

(No. 2361.) *System of Electric Distribution and Locomotion.* Josef H. Hallberg.

ABSTRACT: The report considers the several systems in use, viz.: The direct-current low voltage system as typified in the equipment of the N. Y. Central Railway Terminal in New York City and suburban lines; the single-phase alternating current commutator type motor, as employed on the New York, New Haven & Hartford Railroad, and which obviates the necessity of converting alternating current to direct current in the sub-stations; and the system of multiphase distribution (usually three-phase) necessitating two overhead conductors and the rail as the third conductor.

The objection to the use of the multiphase distribuion is chiefly on account of the complicated construction of frogs and cross-overs.

Mr. Hallberg proposes to use a traveling sub-station—in other words, he locates his sub-station in the locomotive, an idea first suggested by Mr. H. Ward Leonard.

In the Hallberg system it is proposed to install a motor-generator set on the locomotive, consisting of a single-phase Synchronous motor which receives current direct from the line, and to provide a three-phase A. C. generator of special construction consisting of a double set of poles, of which one or both can be energized, changing the frequency from twenty-five to fifty cycles so as to obtain the desired torque at the various rates of speed demanded by the transmitters.

In view of the careful attention the writer has given to the various steps in the operation to meet the conditions demanded in railway service, the report grants to him the award of a Certificate of Merit. (*Sub-Committee*, W. C. L. Eglin, Chairman; Richard Gilpin.)

(No. 2384.) *Moving Platforms.* Max E. Schmidt, New York.

ABSTRACT: The invention is covered by U. S. letters patent No. 440,725, Nov. 18, 1890, granted to M. E. Schmidt and I. L. Silsbee, and No. 747,090, Dec. 15, 1903, granted to applicant. The Committee granted the Longstreth award to the inventors (see report No. 1769) for the first-named invention.

The essence of the first invention consisted in the use of a flexible traveling rail in driving a high-speed platform. The low-speed platform was practically the platform of our ordinary car carried on two axles and four flanged wheels, with the difference that the platform or body is carried outside of the wheels, the space between the wheels being occupied by the high-speed platform. This platform was carried upon two continuous flexible rails upon which it rested, and the rails themselves rested edgewise upon the tops of the treads of the car wheels mounted on the axles of the slow-speed platform. [An installation of this description was successfully operated at the Expositions in Chicago, Paris and Berlin.]

It was found, however, that the continuous flexible rails were unable to stand the constant bending, and this fact led to the complete change of the system in accordance with the design and construction now submitted and covered with the more recent patent (No. 747,090) of applicant.

In the new form, the idea of a car mounted on traveling axles is entirely abandoned. The platforms are six feet long and are supported every two feet nine inches by wheels mounted on axles running in stationary bearings, the wheels being proportioned to give the desired speed to the respective

platforms. These axles are driven by electric motors placed about seventy-five feet apart. The platforms are linked together by pivotal joints and are guided by a central fixed rail and two sets of horizontal guide wheels straddling the rails, attached to each platform.

The report finds that from an engineering standpoint the patent of Schmidt, here under consideration, represents a substantial improvement over the original invention of Schmidt and Silsbee. The construction is more substantial; the flexible rail is altogether eliminated; the greater part of the machinery is stationary and will permit of inspection at any time; much sharper curves are admissible; and the possibility of serious accidents from derailment or other cause appears to be remote.

The report further states that these recent improvements have been made with the view of bringing the moving platform into daily practical use as a means of transportation in large cities, and not merely for amusement purposes. It is noted, also, in passing, that no less than 12,000,000 passengers have been carried on the three platforms already built without injury to a single passenger.

The report recommends the award to the inventor of the John Scott Legacy Premium and Medal. *(Sub-Committee,* Arthur Falkenau, Chairman; Chas. E. Ronaldson, James Christie.)

(No. 2385.) *Historic Collection of Incandescent Electric Lamps.* Wm. J. Hammer, New York.

ABSTRACT: This collection, which was honored at the recent world's fair in St. Louis by the award of a "Grand Prize," is the result of continuous and vigilant efforts on the part of Mr. Hammer covering the past twenty-five years, and includes over 1000 specimens, illustrating every step of the development of this type of lamp.

Mr. Hammer's application is accompanied by a photograph of his collection, and its priceless value from the historical standpoint is approved and endorsed by most eulogistic letters from the most noted electrical engineers of both hemispheres. The award of the Elliott Cresson Medal is made to Mr Hammer. *(Sub-Committee,* Chas. J. Reed, Chairman; Thos. Spencer.)